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THE RELATION OF WHEAT PROTEIN TO BAKING QUALITY II. SASKATCHEWAN HARD RED SPRING WHEAT CROP OF 1929

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The conclusion was reached by Larmour (1930) that when the quality of wheat is estimated by using a baking formula including $KBrO_3$, the correlation between crude protein of wheat and loaf volume is high enough to justify use of protein in predicting quality. The material on which the study was based consisted of hard red spring wheats grown in Saskatchewan in the years 1926, 1927 and 1928.

The season of 1929 produced a crop of exceptionally high average quality, both in respect to grade and baking strength. In the southern and central portions of the province, dry weather during the latter part of the growing season resulted in lowering of yield and raising of protein content, while in the northern areas, plentiful rain favored the production of high yields and lower protein content. The result was that with samples procured from the whole wheat-growing area, the range of protein was very great, being in fact 7% to 19.3% for common wheat. The autumn was marked by a long period of dry weather so that the whole crop was harvested in excellent condition and the amount of damaged grain was very small. With a wide range of protein values, and with samples free from damage, it seemed a most opportune time to carry further the investigation of the relationship of protein of wheat and strength of flour.

The material upon which the present study was based, consisted of 665 samples of hard red spring wheat grown at points well distributed over the wheat-producing areas of Saskatchewan. They included 342 samples of Marquis, 173 of Reward and 150 of Garnet. These numbers do not represent the relative distribution

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of the three varieties in Saskatchewan. Reward and Garnet have been introduced rather recently and are not at present grown on a very large scale. For the purpose of this study, however, the inclusion of a relatively large number of the samples will lead to no very grave misconceptions. Reward is of practically the same quality as Marquis and is usually high in protein. Garnet is lower in protein than Marquis and somewhat lower in quality. The result of including such a number of Garnet samples is therefore to widen the spread of loaf volume values in a given protein range, thus decreasing the correlation coefficient. The correlations on the whole series tend to be minimum rather than maximum values.

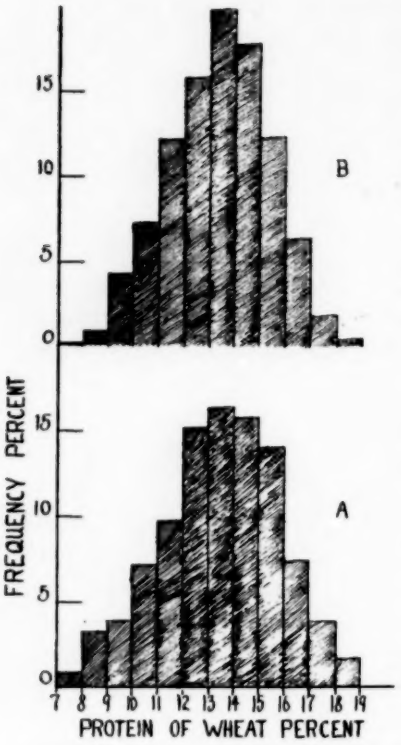

Figure 1. Frequency distribution of wheat protein—1929 crop

A. The 665 samples used in this study.

B. From data obtained by Birchard and Aitken (1930) with 8089 samples.

The extent to which this group of samples was representative of the 1929 crop of Western Canada may be judged by comparing the protein distribution frequency with that obtained with the 8089 samples analysed by Birchard and Aitken (1930) in compiling the protein map for the 1929-30 crop. These two frequency distributions, shown in Figure 1, indicate that our 665 samples were fairly representative of the whole crop in respect to protein content. The chief differences occur in the extreme ranges. Our material shows greater frequencies in the 7-8, 8-9, 17-18 and 18-19 classes, due doubtless to the large number of Garnet and Reward samples.

These samples were milled on an Allis-Chalmers experimental mill: a straight flour, representing on the average 95% of the total flour, being taken. After aging for two months in cotton sacks, the flour was baked by the basic, bromate and blend-bromate formulae, the details of which have been given by Larmour (1930). Only one essential change was made from the procedure used in

the previous study. In the blend-bromate formula, 50% club wheat flour was used in place of 40%. The change was made because in preliminary trials it was observed that some of the higher protein flours showed very little effect of this admixture and it was considered advisable to increase the amount of soft flour sufficiently to ensure that even the very strongest flours would show a reduction of volume when compared with the volumes by the bromate formula. Without using this precaution, the blend-bromate values in the higher protein ranges might have proved meaningless for purpose of comparison.

In studying the data, the loaf volume has been used as the criterion of strength. A baking score in which the other characteristics of the bread are taken into account is considered a better measure of strength, but such values are likely to introduce curvilinearity of regression. The statistics obtained from the baking results are shown in Table I.

TABLE I

VARIOUS CONSTANTS CALCULATED ON THE WHOLE SERIES (665 SAMPLES)

	Baking Method		
	Basic	Bromate	Blend
Mean Protein of Wheat $\bar{x}$	13.483	13.483	13.483
Mean Loaf Volume $\bar{y}$	585.432	712.122	586.222
Standard Deviation of x	2.289	2.289	2.289
Standard Deviation of y	56.881	123.213	65.108
Coefficient of Correlation r_{xy}	+.6302	+.9063	+.8378
Probable Error of r	.0158	.0047	.0078
$r/P.E.$	40	194	107
Correlation Ratio	.6702	.91913	.84077
Coefficient of Regression	15.658	48.779	23.828

The correlation coefficients for protein of wheat and loaf volume as determined by the three baking formulae were:

Basic formula ..... $r = +.630 \pm .016$
Bromate formula ..... $r = +.906 \pm .005$
Blend-bromate formula ..... $r = +.838 \pm .008$

These all are significant and indicate decided relationship of the variables.

From the standpoint of practical utility of the relationship we are interested in knowing the extent to which protein may be used for predicting baking strength. If we consider $(1 - r^2)$ as an estimate of the fraction of the total variance of y that is independent of x, we have for the three cases in question:

Formula	Fraction of Variance of Loaf Volume Independent of Protein	Fraction of Variance of Loaf Volume Dependent on Variation of Protein
Basic	60%	40%
Bromate	18%	82%
Blend-Bromate	30%	70%

These results are interesting in view of the fact that it has been the custom generally to consider the fraction of the variance that is independent of the quantity of protein, as attributable to qualitative differences of the protein. When this fraction can be reduced to 18% by a simple change of baking formula, one is led to surmise that if manipulative errors could be entirely eliminated, nearly all of the variance of loaf volume might be attributed to quantitative variation of the protein. One might go further and hazard the conclusion that a baking formula giving results such that 82% of the variance can be definitely accounted for is more desirable than one by which more than half of the variability must

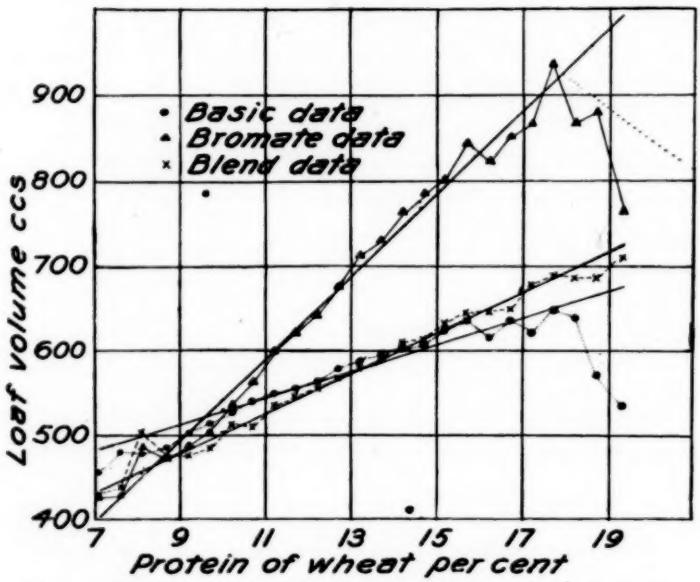

Fig. 2. Regression of loaf volume on protein for the whole series (665 samples)

be attributed to some indeterminable factor. In our opinion, the bromate formula is much more satisfactory than the basic formula.

Regression of Loaf Volume on Protein

The high degree of correlation of loaf volume and protein of wheat can be used to estimate the probable baking quality from

the protein value, by having recourse to the regression function of loaf volume on protein. This function represents the most probable value of loaf volume for any value of protein.

If the regression is linear, the function may be simply described by a straight line. Non-linearity may be due to two different conditions. In one case the value of the regression coefficient $r_{xy}\frac{\sigma_y}{\sigma_x}$ may change continuously with changes of x, and in the other it may be constant for many successive values of x and commence changing only beyond a certain point. In other words the regression may be curved for the whole range or it may be linear for part of the population and non-linear for the remainder. It is necessary first to determine if it is linear or not, and if it is not, to ascertain what values of x account for the greater departures from linearity.

In Figure 2 the regression line of loaf volume (basic formula) on protein is shown together with the actual averages for the protein ranges on a 0.5% increment basis. In the terminal ranges, the average values show decided departure from the straight line, indicating that the regression may be non-linear. To test this, Blakeman's criterion of linearity was applied with the following results:

$$\eta = 0.6702$$
$$(\eta^2 - r^2) = 0.05199$$
$$(\eta^2 - r^2)/P.E. = 4.49$$

As the difference is 4.5 times its probable error, it may be assumed to be significant, and by this test, the linear regression line apparently is not admissable as the most probable value for the various protein classes.

Fisher (1930) has criticized Blakeman's criterion because it does not take account of the number of arrays involved and therefore provides no means for estimating what values of $(\eta^2 - r^2)$ are permissible. Applying Fisher's method for testing straightness of the regression line, the following values were obtained:

Variance	Degrees of Freedom	Sum of Squares	Mean Square	$\frac{1}{2} ln.$	Difference—z
Within Arrays	640	1896.39	2.963	.5426	
Between Arrays due to Deviations from Linear Regression	23	178.92	7.779	1.0258	.4832

The significance of the difference between two variances may be tested by making a transformation:

$$z = \tfrac{1}{2} \ (ln \ V^1 - ln \ V^2)$$

where V_1 and V_2 are the variances.

By reference to the table of 1% points of the distribution of z it is seen that for $n_1 = 23$, $n_2 = 640$, the 1% point of z is approximately .300. As the observed value of z is greater than this, it may be concluded that it is significant and that therefore the regression is non-linear.

Thomas (1917), Stockham (1920) and Bailey (1924) made observations regarding the tendency of the loaf volume to increase less rapidly in the higher protein ranges. Bailey (1925) referring to the relation of loaf volume and protein states "the curve accordingly approaches a logarithmic rather than a linear form and would necessitate the use of an exponential value in an equation representing the function of one variable in terms of the other."

At first sight it might seem that our results confirm these observations. It should be pointed out that with either of the tests employed, lack of linearity does not mean that there is simple curvilinearity of regression. In both tests use is made of the function $Sn_p \ (\bar{y}_p - \bar{y})^2$. This is a weighted square difference representing the variance between arrays. Differences in sign of $(\bar{y}_p - \bar{y})$ disappear in the squaring. Hence a series of small values of $(\bar{y}_p - \bar{y})$ alternating in sign might give a value of $Sn_p \ (\bar{y}_p - \bar{y})^2$ great enough to enable one to say that the regression is non-linear, when in reality the straight line might be the best smooth curve that could be fitted to the data.

TABLE II

VARIOUS CONSTANTS CALCULATED ON THE MODIFIED SERIES

Constant	Baking Method	
	Basic	Bromate
No. of Samples N	567	644
Mean Protein of Wheat $\bar{x}$	13.046	13.494
Mean Loaf Volume $\bar{y}$	581	713
Standard Deviation of x	1.845	2.1225
Standard Deviation of y	53.384	119.015
Coefficient of Correlation r_{xy}	+.6315	+.9080
Probable Error of Correlation	.017	.0047
$r/P.E.$	37	195
Correlation Ratio	.6450	.9146
Coefficient of Regression	18.270	50.918

From consideration of the regression of loaf volume (basic formula) on protein, Figure 2, it seemed probable that the line shown does not represent the regression for most of the population. It appears that if the seven highest and three lowest classes

were omitted, the regression coefficient would increase and would be a better measure of regression for the greater number of the population. This was tested by discarding these and recalculating the constants. The new values obtained are given in Table II.

The series was reduced by these changes from 665 to 567 samples. The coefficient of correlation was practically unchanged but the correlation ratio was reduced so that the difference of squares $(\eta^2 - r^2)$ was no longer significant. The regression coefficient was increased, producing the effect of pivoting the regression line about a point near the 12.0-12.4% value of x. Fisher's test applied to this new series showed no significant differences from linearity. This new regression line is shown in Figure 3.

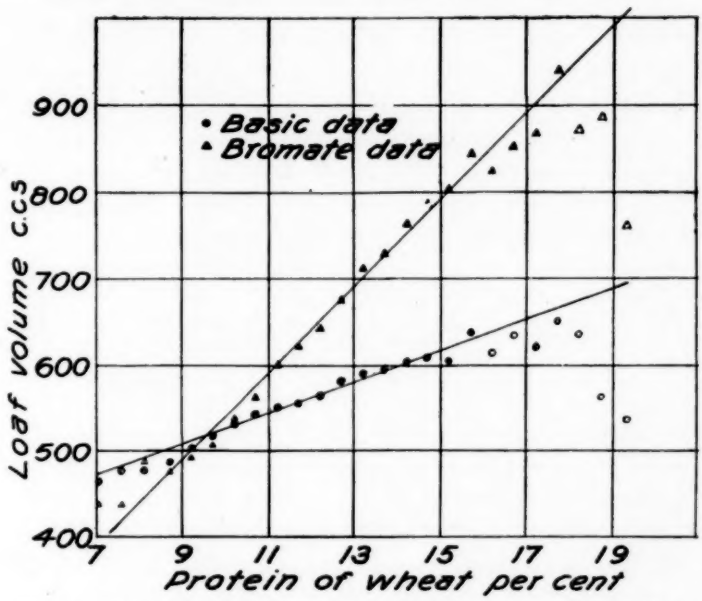

Fig. 3. Regression of loaf volume on protein for the modified series.

It seems reasonable to assume that this regression fits the data up to and including class 15.0-15.4% better than the one calculated from the whole series. Averages of the classes omitted have been entered in this graph and are shown as unshaded circles. Although the three lowest protein clases were omitted it can be seen that these fit the new regression line very well. It thus is evident that although there is decided non-linearity of regression for the whole series, most of this is due to the higher protein samples, and that for the range 7.0-15.9% the regression is quite linear. Values of $n_p\ (\bar{y}_p - Y)^2$ were calculated in order to ascertain which

arrays contributed most to the non-linearity of the modified series. The value of $Sn_p (\bar{y}_p - Y_p)^2$, the total variance between arrays due to deviation from linear regression, was 44.35. Of this 29.73 or 67% was contributed by the two highest arrays. The total variance of the arrays from 7.0-15.0% including the three lowest arrays is 17.4. The regression line shown in Figure 3 is therefore probably the best that could be fitted to these arrays. It may be concluded that for the range 7.0-14.9% protein the basic formula gives values that show quite linear regression, and that for higher protein samples, the linear regression coefficient is unreliable for predicting loaf volume from protein content.

Regression of Bromate Loaf Volume on Protein

The line of regression of bromate loaf volume on protein, and the actual averages for the various protein classes are shown in Figure 2. By inspection it can be seen that the values of the higher classes tend to produce curvilinearity in the upper part of the curve. This effect is very likely due to the fact that 1 mg. of $KBrO_3$ is insufficient to give maximum loaf volumes. Some trials with high protein flours of this crop showed that those over 17% protein gave increasing response to bromate in dosages up to 3 mg. per 100 g. flour.

Blakeman's tests for linearity of regression gave the following results:

$$\eta = .91913$$
$$\eta^2 - r^2 = .02342$$
$$\eta^2 - r^2/P.E. = 2.93$$

The difference of squares is barely significant.

While Fisher's test gave:

Variance	Degrees of Freedom	Sum of Squares	Mean Square	½ *ln.*	Difference—*z*
Within Arrays	640	2506.88	3.917	.6827	
					.7174
Between Arrays Due to Deviation from Linear Regression	23	378.37	16.451	1.4001	

The 1% point is approximately .300 and the deviation from linearity may be considered quite significant.

Examination of the graphs in Figure 2 indicates that if the values for the three highest and three lowest protein classes were omitted, the regression line would more nearly coincide with the

actual averages, as these end values tend to decrease the values of the regression coefficient. A slight anti-clockwise rotation of the regression line about the point $x = 12.2$, $y = 640$, would materially reduce the deviations from linearity.

To confirm this postulate, the three terminal arrays were omitted from each end and the constants recalculated. This reduced the number of samples from 665 to 644. Values of the constants obtained with this modified series are given in Table II. The correlation coefficient and the correlation ratio were both very slightly raised. The regression coefficient was increased somewhat and the variance due to deviations from lineat regression was considerably reduced. However, Fisher's test showed that the difference between this variance and the variance within arrays is significant.

Variance	Degrees of Freedom	Sum of Squares	Mean Square	$\frac{1}{2} ln.$	Difference—z
Within Arrays	625	2386.92	3.819	.6700	
					.4922
Between Arrays due to Deviations from Linear Regression $z = .4922$	17	173.820	10.225	1.1622	

This is greater than the 1% point of z and the difference is therefore significant.

The new regression line is shown in Figure 3. From this graph it looks as though most of the deviations from regression occur in classes in the range 16.0-17.4%. As with the simple data, values of $n_p\ (\bar{y}_p - Y)^2$ were calculated in order to find where most of the deviations occur. The arrays above 15.4% account for 65% of the variance, and most of this is due to negative values of $(\bar{y}_p - Y_p)$. It seems probable therefore that the regression is linear to 15.5-15.9% protein and beyond that decidedly curvilinear.

Results Obtained With the Blend-bromate Formula

The various statistics calculated for the blend-bromate data are given in Table I. It is worthy of note that while the average loaf volume by this method is not significantly greater than the loaf volume by the simple formula, the correlation coefficient is much higher, being $r_{xy} = + .838 \pm .0078$. This degree of correlation indicates that the protein content of the wheat may be used as a practical estimate of the loaf volume to be expected in a 50-50

blend with soft flour. The regression shown graphically in Figure 2 appears to be linear. Applying Blakeman's test:

$$\eta = .8408$$
$$\eta^2 - r^2 = .0049$$
$$\eta^2 - r^2/P.E. = 1.34$$

The deviations from linearity are not significant.

By Fisher's test we obtain:

Variance	Degrees of Freedom	Sum of Squares	Mean Square	$\frac{1}{2} ln.$	Difference—s
Within Arrays	640	1292.042	2.0188	.3513	.0586
Between Arrays due to Deviations from Linear Regression	23	52.2070	2.2699	.4099	

The variance due to deviation from regression is not significantly greater than that found within the arrays and it may be assumed that the regression is essentially linear. The value of $n_p (y_p - Y_p)^2$ were calculated and it was found that class 8.0-8.4% accounts for 40% of the variance attributable to deviation from regression.

These results show that the blend formula yields reliable relative values for samples over the whole range of protein content. It should be noted that in the lower range 13.0-13.4% the average loaf volume is lower than that obtained by the basic formula, and this is reversed in the higher ranges. Thus the blend-bromate tends to accentuate the characteristics of the samples in the extreme ranges.

Summary

665 samples of hard red spring wheat grown in Saskatchewan in 1929, were milled and baked. Three baking formulae, namely the basic, the bromate with .001% $KBrO_3$ and a 50-50 blend with soft flour +0.001% $KBrO_3$ were used.

Correlations between loaf volume and crude protein of wheat were, for the basic formula $r = + .630 \pm .016$, bromate $r = + .906 \pm .005$ and for the blend-bromate $r = + .838 \pm .008$.

A study of the regression of loaf volume on protein of wheat led to the conclusions that with values obtained by use of the basic formula, the regression is linear for samples having protein 7.0-14.9%; with the bromate results it is linear from 7.0-15.9%; with the blend-bromate results, the regression is linear over the whole range examined, namely 7.0-19.3%.

As a means for estimating relative strength, the blend baking

formula is effective over the whole range of protein whereas the other two methods fail in the higher protein classes.

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A STUDY OF WHEAT PROTEINS IN RELATION TO PEPTIZATION AND BAKING STRENGTH

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Since the time millers first attempted to apply tests to their flour in order to see that it came up to certain desired standards, there has been a need for a simple, rapid test that could be applied to the wheat itself for the purpose of predicting the quality of flour that could be milled from it. At present the protein test is used in binning the wheat for storage and in checking the mill mix before going to the rolls. The usefulness of this test depends on the fact that protein of wheat is correlated with the baking quality of flour milled therefrom. A supplemental test of quality, that could be applied as rapidly, would be of considerable value as it would serve as a check on the protein test.

Furthermore, such a test would be of very great advantage to the plant breeder as it would enable him to make a prediction of probable quality long before he could obtain quantities sufficient for a milling and baking test. Selection of bread wheats must be made with quality as an important factor and if this could be done early in the program, much useless work might be eliminated. With these considerations in mind, the peptization method was applied to whole ground wheat in order to see whether or not there might be obtained from such material, information of the type obtainable from flours and reported on by Gortner, Hoffman and Sinclair (1927), Geddes and Goulden (1931), and Harris (1931).

This ground wheat or meal may be made with a small grinder or coffee mill from a relatively small sample of clean wheat, and differs chiefly from commercially and experimentally milled flour in that it contains the bran and germ structures, as well as the endosperm. The particles composing the meal are also much larger and more irregular in size.

A series of 15 wheat samples from the 1929 crop was used for this study. These wheats appeared to be fairly representative of wheat obtained from the Saskatoon district and included only one variety, Marquis. They were free from frost or rust damage and of contract grade, ranging in protein content from 9.9 to 16.5%. They had previously been milled and the resultant flours baked, analyzed and peptized by solutions of $MgSO_4$ and KBr. Two baking methods were used, the basic, using flour, water, salt, sugar

and yeast, and the improver, containing in addition, 1% diastatic malt and 0.001% $KBrO_3$ or 3% diastatic malt and 0.5% Arkady for higher protein flours.

The ground samples, as used for determining total protein of these wheats, were used in finding the protein extracted by various solvents. The meal was ground in a coffee mill, about 30 g. of clean wheat being used for each sample. The samples were kept in a tightly corked glass bottle after grinding until used for this experiment.

TABLE I

PROTEIN CONTENTS AND PERCENT OF TOTAL PROTEIN EXTRACTED BY THREE SOLVENTS FOR 15 WHEATS AND THE FLOURS MILLED THEREFROM (13.5% MOISTURE BASIS)

			Percent total protein extracted by					
	Protein content		H_2O		$MgSO_4$		KBr	
No.	Flour	Wheat	Flour	Wheat	Flour	Wheat	Flour	Wheat
	%	%	%	%	%	%	%	%
4	12.6	14.8	21.6	15.5	15.8	25.9	27.9	29.0
5	11.9	13.8	23.5	15.0	16.1	23.5	31.4	30.4
31	13.6	15.6	20.9	14.8	17.7	21.8	26.7	28.9
32	11.5	13.4	23.1	16.9	17.8	29.7	30.8	32.6
33	10.6	12.2	23.2	15.6	19.7	25.4	31.5	32.2
35	14.2	16.4	18.1	14.5	15.8	21.3	28.8	27.9
36	13.4	15.1	20.1	14.0	15.4	20,4	27.4	28.6
41	12.5	13.5	20.5	16.6	17.3	25.9	28.9	32.4
43	14.7	16.5	16.9	16.1	15.7	20.0	21.4	27.7
44	14.5	16.5	19.6	15.4	16.6	21.5	22.7	29.1
61	9.0	9.9	18.0	22.2	20.5	26.2	34.9	34.5
62	11.2	12.1	17.8	19.7	17.5	26.0	29.7	34.1
63	9.1	10.4	19.0	21.5	19.5	26.2	34.0	34.8
64	10.8	11.8	19.1	18.8	16.3	24.3	29.2	33.6
65	13.9	15.9	20.1	15.8	15.0	20.3	26.0	28.7
Average			20.1	16.8	17.1	23.9	28.7	30.9

Six gram samples of the whole wheat were weighed into 250 cc. flasks, 150 cc. of 0.5N KBr or $MgSO_4$ added, and kept in suspension for one hour by frequent shaking. At the end of this period, several hours were allowed for the particles to settle, then the supernatant liquid was decanted from the residual meal, aliquoted into two 50 cc. portions and the dissolved nitrogen determined by the Kjeldahl-Gunning procedure. A series was similarly treated with distilled water because, in a former study, the influences of length of extraction period and temperature of extraction medium upon per cent total protein extracted from flours of various protein contests were investigated, and it was observed that the percentage of total protein extracted by the water varied inversely with the protein content of the flours, corresponding to the peptizing action of the salt solutions. It was thought desirable to ascertain if this held true for whole wheat meal.

The solutions cleared quite rapidly upon standing, the bran particles in particular settling almost immediately after agitation. The data obtained from these determinations, calculated as per cent of total protein, are shown in Table I with protein content of the wheats and the data similarly obtained with the corresponding flours. Table II shows the peptized and non-peptized protein fractions, calculated for the wheat for each of the extraction media. The total wheat protein is also given for each sample with the loaf

TABLE II

TOTAL WHEAT PROTEIN WITH THE PEPTIZED AND NON-PEPTIZED PROTEIN FRACTIONS AS DETERMINED ON WHOLE WHEAT MEAL FOR THE 15 WHEATS WITH COMPARATIVE BAKING DATA FOR THE CORRESPONDING FLOURS (13.5% MOISTURE BASIS)

				Extractions calculated as per cent of sample					
				H_2O		$MgSO_4$		KBr	
No.	Total Protein	Loaf Volume Basic	Improver	Peptized	Non-peptized	Peptized	Non-peptized	Peptized	Non-peptized
	%	cc.	cc.	%	%	%	%	%	%
4	14.8	455	555	2.29	12.51	3.83	10.97	4.29	10.51
5	13.8	465	515	2.07	11.73	3.24	10.56	4.20	9.60
31	15.6	525	615	2.31	13.29	3.40	12.20	4.50	11.10
32	13.4	490	540	2.26	11.14	3.98	9.42	4.37	9.03
33	12.2	505	525	1.90	10.30	3.10	9.10	3.93	8.27
35	16.4	545	630	2.38	14.02	3.49	12.91	4.58	11.82
36	15.1	534	605	2.11	12.99	3.08	12.02	4.32	10.78
41	13.5	495	558	2.24	11.26	3.50	10.00	4.37	9.13
43	16.5	505	644	2.66	13.84	3.30	13.20	4.57	11.93
44	16.5	535	650	2.54	13.96	3.55	12.95	4.80	11.70
61	9.9	445	410	2.20	7.70	2.59	7.31	3.41	6.49
62	12.1	470	490	2.38	9.72	3.15	8.95	4.13	7.97
63	10.4	435	440	2.24	8.16	2.72	7.68	3.62	6.78
64	11.8	475	510	2.22	9.58	2.87	8.93	3.96	7.84
65	15.9	505	625	2.51	13.39	3.23	12.67	4.56	11.34

volumes obtained by two methods of experimental baking for 15 flours milled from these wheats.

Turning first to Table I, it will be observed that the KBr extracts a higher percentage of total wheat protein than $MgSO_4$. Comparing next the relative amounts of protein extracted from wheat and the corresponding flour, it is seen that with wheat meal the KBr (except in samples 5, 35, and 61) and $MgSO_4$ extract more and the H_2O less than with the flour. A surprising fact is that in 13 out of the 15 samples H_2O extracts more total protein than $MgSO_4$. This apparently points to a coagulation of water-soluble flour proteins by $MgSO_4$.

The average per cent of total protein extracted from these wheats and flours by the three media shows that KBr removes 2.2%, and $MgSO_4$ 6.8% more protein from the wheats than from the flours. It would appear from this that the difference in pep-

tizing action of these two salts shows more markedly with flours than with whole wheat meal. Distilled water extracts 3.3% less of the total protein from the wheats than from the flours.

The question of what proteins are removed from wheat meal by $MgSO_4$ and not by H_2O is rather difficult to answer in view of the confusion regarding the identity of the proteins removed by inorganic salt solutions. Gortner (loc. cit.) states that "the salt-soluble protein fraction does not represent a mixture of albumin and globulin, nor does it represent the non-gluten proteins." He further questions the current definition of globulins and the salt-soluble fraction in general. If globulins be defined as "simple proteins insoluble in pure water but soluble in dilute saline solutions," one would expect that the quantity of protein removed by salt solutions in addition to that extracted by water would approximate the globulin content of the wheat. Bailey (1925) states that Osborne found approximately 0.6% of globulin in wheat, the greater part being contained in the embryo. The differences between the protein removed by the H_2O and $MgSO_4$ from wheat are much greater than can be accounted for by this quantity of protein, even provided that it were all contained in the germ. When KBr is considered, the situation is even worse as the differences between the protein removed by water and salt are still larger. This evidence would appear to substantiate Gortner's contention that the current definition of globulins is not entirely correct.

The peptized and non-peptized fraction (calculated as per cent of wheat) and total wheat protein with comparative baking results for the corresponding flours are shown in Table II. From this table, it is evident that the higher protein wheats as Nos. 35, 43 and 44 produce flours which yield the largest loaves. The lower protein wheats are associated with correspondingly lower loaf volumes, while the lowest protein members of the series, Nos. 61 and 63, showed very low baking strength. These relations were more evident when a flour improver was included in the baking formula.

The non-peptized protein fraction is the largest for the high protein wheats which produced the largest loaves, while the low protein wheats which produce flours of low baking strength have the smallest non-peptized fraction. Water shows the highest and KBr the lowest non-peptized residue throughout this series, while $MgSO_4$ is intermediate in this respect. The non-peptized fraction obviously decreases in going from KBr to H_2O and agrees with the evidence presented in Table I, where it was shown that KBr

TABLE III

STATISTICAL ANALYSIS FOR 15 WHOLE WHEAT FLOURS

	H_2O		$MgSO_4$		KBr	
	Basic	Improver	Basic	Improver	Basic	Improver
r_{ae}	+0.7775±0.0688	+0.9720±0.0096	+0.7775±0.0688	+0.9720±0.0096	+0.7775 ±0.0688	+0.9720±0.0096
r_{ad}	−0.8445±0.0499		−0.7199±0.0839		−0.9351±0.0219	
r_{be}	+0.2544±0.1628	+0.5427±0.1228	+0.3837±0.1485	+0.5717±0.1172	+0.7679±0.0714	+0.9829±0.0061
r_{bc}	+0.4985±0.1308		+0.5000±0.1305		+0.9239±0.0255	
r_{ce}	+0.7920±0.0649	+0.9696±0.0104	+0.7881±0.0660	±0.9677±0.0111	+0.7693±0.0711	+0.9652±0.0119
r_{de}	−0.7613±0.0732	−0.8314±0.0537	−0.6491±0.1007	−0.7306±0.0812	−0.7105±0.0862	−0.9017±0.0325
$_br_{ce}$	+0.7934±0.0645	+0.9601±0.0136	+0.7457±0.0773	+0.9597±0.0137	+0.2439±0.1637	+0.8111±0.0596
$_cr_{be}$	−0.2653±0.1618	+0.2800±0.1604	−0.0193±0.1739	+0.4026±0.1459	+0.2340±0.1646	+0.9120±0.0714
R_{abcde}	+0.8084±0.0603	+0.9719±0.0096	+0.7881±0.0660	+0.9729±0.0093	+0.7844±0.0670	+0.9941±0.0020

a—Total Protein
b—Peptized Protein
c—Non-Peptized Protein
d—% Total Protein Peptized
e—Loaf Volume

extracted the highest and H_2O the lowest per cent of total protein from these wheats. It would seem from an inspection of the data shown in Table II that distilled water is as useful as the salt solutions for purposes of determining non-extracted protein in relation to loaf volume.

The correlations obtained when the data from the 15 wheats were treated by a statistical method proposed by Geddes and Goulden (1930) are shown in Table III. The use of a flour improver in baking yielded results more significantly correlated with the other variables studied than the corresponding data obtained by the use of the basic method alone.

Total protein appeared to be very significantly correlated with baking strength. This would appear to justify the prediction of baking strength from a knowledge of protein content of wheat. Non-peptized protein was very similar in its relationship to loaf volume, and therefore also useful as a means of forecasting baking strength for wheats of this type. The correlation of peptized protein with loaf volume increases in significance in going from H_2O to KBr. The correlation

between non-peptized and peptized protein is also highest for KBr. A relatively high negative relationship is evident between per cent of total protein peptized and loaf volume, but the practical significance of this relationship is lessened by the higher correlations shown when total and non-peptized protein are correlated with loaf volume. The partial correlations show increasing relationship between peptized protein and loaf volume in going from H_2O to KBr. Also, the corresponding relation between non-peptized protein and loaf volume is lower for KBr, and tends to increase in approaching H_2O, while the total correlation between these variables remains unchanged, due probably to the influence of the peptized fraction. An analysis of variance was applied to all pairs of r_{ae} and $R_{(bc)e}$ and the results are summarized in Table IIIa. The multiple correlations do not reveal any further information

TABLE IIIa

COMPARISON BY ANALYSIS OF VARIANCE OF TOTAL AND MULTIPLE CORRELATION COEFFICIENTS

Correlation Coefficient	H_2O		$MgSO_4$		KBr	
	Basic	Improver	Basic	Improver	Basic	Improver
r_{ae}	.7775	.9720	.7775	.9720	.7775	.9720
$r_{(bc)e}$	.8084	.9719	.7881	.9729	.7844	.9941
z	.2645+	.....	.3716−	.4672−	.5483−	1.8959+

Value of z at 5% point +.7788

with the exception of the constants calculated from the improver and KI data. No indications of a significant loss of information are evident.

Correlations between total protein, per cent of total protein peptized by the three solvents and loaf volume for the 15 flours milled from these wheats are shown in Table IV. A statistical

TABLE IV

CORRELATIONS OBTAINED FROM THE FLOURS MILLED FROM THE 15 WHEATS

	H_2O	
	Basic	Improver
r_{ae}	+0.7939±0.0644	+0.9761±0.0082
r_{ad}	−0.1039±0.1722	
r_{be}	+0.6591±0.0985	+0.8097±0.0600
r_{bc}	+0.6794±0.0937	
r_{ce}	+0.7686±0.0712	+0.9455±0.0184
r_{de}	−0.0258±0.1740	−0.0381±0.1738
r_{de}	−0.4519±0.1385	−0.7244±0.0827 ($MgSO_4$)
r_{de}	−0.6451±0.1016	−0.8907±0.0360 (KBr)

analysis of the data obtained by extracting these flours with distilled water was also included. It is evident that no correlation exists between per cent of total protein extracted by H_2O and

loaf volume, while the non-extracted protein fraction is highly correlated with baking strength. Less significant values are shown between extracted and non-extracted protein and between extracted protein and loaf volume. The same relationships are shown between per cent of total protein peptized by $MgSO_4$ and KBr and loaf volume for these flours as has been shown in previous peptization studies.

Comparing the statistical data obtained from the wheats and the flours milled therefrom, as shown in Tables III and IV, the only striking difference is the fact that apparently no correlation exists between per cent of total protein extracted by H_2O and loaf volume for the flours while in every other case these variables give significant negative values. The results obtained by Geddes and Goulden (loc. cit.) and Harris indicated that the relative value of the peptized and non-peptized fractions in relation to loaf volume depended upon the salt used. With a salt of low peptizing power the non-peptized fraction was the more valuable, while with salts of high peptizing power the peptized fraction was the more valuable. Per cent of total protein peptized was found to be less important. In view of this work, the lack of correlation between per cent of total protein removed by water and baking strength would not seem to be of any great practical importance.

It would seem from the evidence presented in these tables that as much information relative to baking strength may be gained from a knowledge of total and non-peptized protein of wheat meal as from total and non-peptized protein of the flour. It would follow that insofar as protein peptization is concerned, experimental milling seems to be unnecessary.

In a previous peptization study it was noticed that when the suspension of flour and liquid had been shaken for only a few minutes before allowing to settle, the results obtained were relatively the same as when one hour of agitation was employed. In order to ascertain whether a shorter period could be employed for determining the protein solubility of wheat meal, this series of 15 wheats were again peptized by KBr, using a shaking period of 10 minutes followed by a settling period of one hour. These results, as well as those obtained by the longer method computed as per cent of total protein extracted, are shown in Table V. While the values obtained for the shorter method are lower, they show the same relative order of magnitude as those given by the usual longer procedure. The data obtained by these methods were cor-

related and yielded a value for $r = +.9460 \pm .0216$. It would appear from the strength of this relationship that the shorter method gives results as indicative of the baking strength as the longer method. It would follow, therefore, that by employing the shorter method the entire determination of protein peptizability may be done in slightly more than an hour longer than the time required for the protein determination.

TABLE V

COMPARATIVE PEPTIZATION DATA OBTAINED BY TWO DIFFERENT EXTRACTION PERIODS FROM 15 GROUND WHEATS

No. of sample	Per cent of total protein extracted	
	One hour shaking period 3-4 hour settling period	10 minutes shaking period One hour settling period
	%	%
4	29.0	20.9
5	30.4	20.5
31	28.9	17.2
32	32.6	22.3
33	32.2	21.7
35	27.9	16.0
36	28.6	17.7
41	32.4	21.9
43	27.7	16.9
44	29.1	18.9
61	34.5	25.4
62	34.1	24.7
63	34.8	23.1
64	33.6	23.7
65	28.7	19.3

Figure 1 is a dot diagram of total wheat protein and improver loaf volume for the 15 wheats. The dots are distributed near the regression line, and indicate a comparatively steady increase in loaf volume with increasing wheat protein.

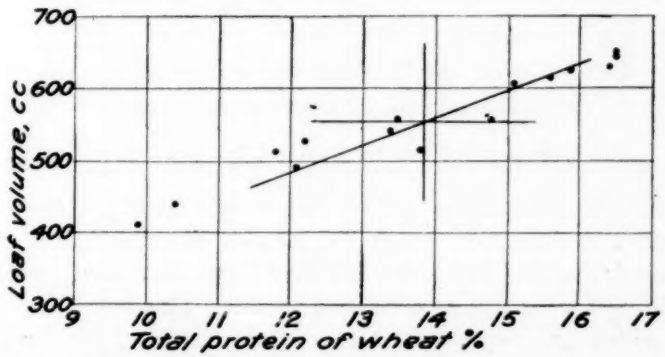

Fig. 1. Total protein of wheat and loaf volume (improver formula): $N = 15$, $r = + 0.9720 \pm 0.0096$.

Figures 2, 3 and 4 are dot diagrams of the non-extracted protein, after treatment with KBr, $MgSO_4$ and H_2O respectively, and improver loaf volume. The distribution of the dots is very

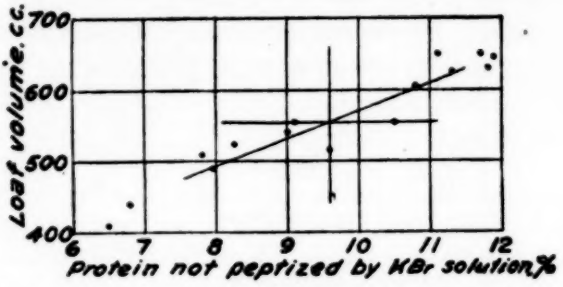

Fig. 2. Non-peptized protein (KBr) and improver loaf volume: $N = 15$, $r = + .9652 \pm 0.0119$.

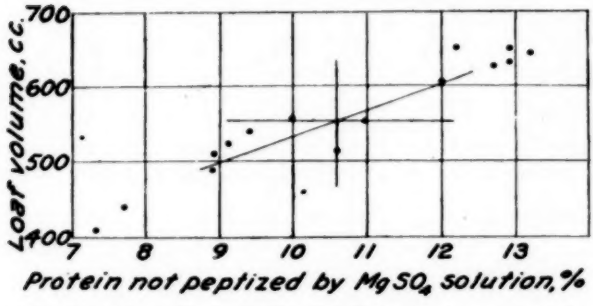

Fig. 3. Non-peptized protein ($MgSO_4$) and improver loaf volume: $N = 15$; $r = + .9677 \pm 0.0111$.

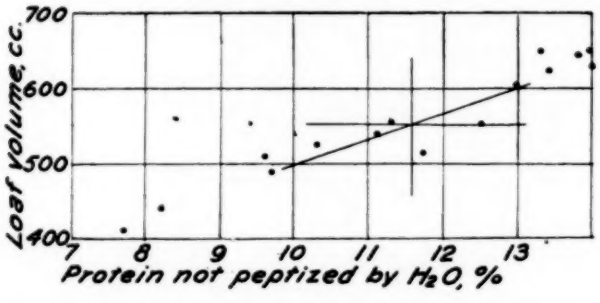

Fig. 4. Non-peptized protein (H_2O) and improver loaf volume: $N = 15$; $r = + .9696 \pm 0.0104$.

similar for these diagrams and all resemble Figure 1 closely. There is evidently a strong tendency for similar distribution in the diagrams depicting the relations between non-extracted protein and loaf volume for various extraction agents. The correlation coefficients, which are represented concretely in the four figures, are very nearly of the same magnitude as would be inferred from the similarity between the scatter diagrams.

Summary

A series of 15 wheats of contract grade were ground into wheat meal and extracted with solutions of $MgSO_4$ and KBr, and distilled water. The flours milled from these wheats were baked and also extracted with these media. The extraction data was calculated as per cent of total protein, and as extracted and non-extracted protein as per cent of sample.

In comparing the per cent of total protein extracted from the wheats and flours, it was found that KBr extracted a larger percentage of total protein than $MgSO_4$ from the flour series, but in the wheat series, while this relation of the relative peptizing action of the salts also held, the difference was smaller. Distilled water extracted more of the flour protein and less of the wheat protein than $MgSO_4$. This salt appeared to exert a coagulating effect upon the flour protein.

Higher correlations were obtained with the improver than wth the basic loaf volume. Total and non-extracted protein gave very significant relationships with loaf volume, showing that loaf volume may be predicted equally as well from a knowledge of total and non-extracted wheat protein as from a knowledge of total and non-extracted flour protein. Per cent total protein peptized and extracted protein were not as significantly related to baking strength as total and non-peptized protein.

The data obtained from the distilled water extractions gave very similar results when correlated with loaf volume as the corresponding values obtained with the salt solutions. When the flours were considered, the per cent of total protein removed by water did not show any relationship with baking strength while for the wheats a strong negative correlation was shown corresponding to the values obtained with $MgSO_4$ and KBr.

A short (10 min.) method of peptizing wheat flour proteins was also used with this series of wheats, employing KBr as an extraction agent. The data obtained was correlated with that obtained by the usual one hour method, yielding a value for $r = + .9460 \pm .0216$. The shorter method would appear to be equally efficient for the purpose of determining peptizable protein.

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HYGROSCOPICITY OF WHEAT

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The moisture content of gels such as silicic acid gel, gelatine, wood, starch and flour, varies with the relative humidity of the environment. According to the data of Fairbrother (1929), and Coleman and Fellows (1925), the different wheats show considerable variation in their hygroscopicity and on storage their moisture content is only partially equalized. Among several varieties a difference as great as 2.4% was found.

In storing wheat and wheat flour no strict limit of moisture can be given. One variety spoils at a moisture content which does not effect any damage of the other. In tempering and heat-treating of wheat and wheat flour it is not enough to correlate time and temperature only with the moisture percentage, but these variables have to be modified with the different varieties.

An attempt was made to explain this phenomenon with the supposed differences in the state of humidity. The moisture content being a quantitative factor, the relative vapor pressure of the material has to be considered as the potential one, this factor alone determining the more or less active state of the water contained by the material in question.

Experiments have been reported recently by Fairbrother (1929) who investigated the hygroscopicity of wheat and wheat flour. To this end wheats from six different countries with a moisture content of 9.8-18.5% were mixed by pairs and it was found that in the equaliation of the moisture content equilibrium was reached within three days. A considerable difference was found in the moisture content of the wheats investigated. The least difference of 1.5% was encountered between the German and American

samples and the greatest of 2.4% between the American and Indian wheats.

Experimental

To investigate the hygroscopicity of wheat three methods can be used:

1. The wheat is placed in a chamber of known relative humidity. When equilibrium is reached the moisture content is determined. The vapor pressure desired is attained by properly diluted sulfuric acid. This method is not satisfactory, however, for exact determination of the hygroscopicity, because in the case of diluted sulfuric acid no constant state of humidity can be secured. When during the experiment the temperature decreases, an increase of the relative humidity can be observed on putting a hair hygrometer in the thermostat. Moisture condensed on the surface of the wheat samples is rapidly absorbed and is lost afterwards but slowly. According to the variation of the temperature 1.2-2° C. in the vicinity of the saturation point the moisture content increased by 0.3 to 1.2%. Strictly speaking, not even the values obtained in the same chamber are comparable, since the conditions of cooling are by no means equal in the various parts of the instrument. The results thus obtained vary, due to the alternate gain and loss of moisture in the neighborhood of the equilibrium. From this fact the wrong conclusion could be drawn that the final state can be reached within a short time.

2. The vapor pressure of the substance can be read immediately in millimeters, the samples in the thermostat being placed on a spring balance, the air exhausted entirely, water vapor introduced in the chamber and the pressure and weight of the substances measured. This method has been developed recently by Pidgeon and Maass (1930).

3. For comparing the hygroscopicity of different wheats the moisture content at the same relative humidity is determined. For this purpose small quantities of wheat were put in a closed chamber for a longer time to equalize their vapor pressure, then their moisture content was measured. Even after two months, however, no equilibrium was reached either in the equalization of the moisture content of the samples or in the variation of their weight. The difference in the moisture content of dry and wet wheats decreased very rapidly at the beginning, while at the end of the experiment it decreased almost imperceptibly. If a dry and a wet sample of the same wheat are placed in a closed chamber

their moisture content never will be found the same, due to hysteresis. The originally dry wheat contains in every case less moisture than the wet one. For the reason mentioned above the samples were stored for an extended time to equalize their moisture. This done, a dry and a wet sample of every wheat were prepared and placed in a hermetically closed chamber. Their moisture content was determined after two weeks. To eliminate the error caused by hysteresis an average value of the moisture content was taken.

Methods

To compare the hygroscopicity of wheats of different varieties the following method was used. The wheat samples were ground in a Seck mill and 2 g. of the sample was spread on plates of 25 cm^2 surface. To attain a final moisture content of 12% and 13% the plates were placed for a week in two chambers of different relative humidity. The desired relative humidity was obtained by using considerable quantities of flour of 12.2% and of 13.3% moisture content. Nearly one hundred samples were placed in an air-tight chamber at 20° C. After two weeks the wheats were taken out by groups and their moisture content was determined. Every wheat sample having been tested in two or three experiments it was possible to compare the results obtained from experiments performed at different times.

For determining the moisture content, after a preliminary drying for one hour at 40° C., the material was dried in an electric oven for three and a half hours at 105° C. Further drying resulted in a slight gain of weight while a loss of weight was observed in only a few exceptional cases.

After two weeks the difference in moisture content between samples of 12% and 13% ground from the same wheat decreased to 0.2-0.4%. After a period of four weeks a difference of 0.1-0.3% was found. To obtain a characteristic value which would be independent of the original moisture content of the wheat the average of the two data mentioned above was taken.

The hygroscopicity of the wheats was compared at a moisture content of 12.5% because this value may be accepted as the average moisture content of stored wheats grown under continental climate. Having examined wheats from all parts of the world, König (1921) found an average moisture content of 14.01%, with a range of 7% to 20%. As to Hungarian experiments for forty years, the moisture content varies from 8.8% to 16.9%. Kosutany (1912) gives an average value of 12.18% for a six year period.

The Data

In our experiments 286 wheat samples have been examined, of which 200 were Hungarian winter wheats grown in different parts of the country, or if grown in the same place they belonged to different varieties. Of these, 92 samples were of unknown variety, the rest represented 32 varieties. Three wheats were harvested in 1927, 26 in 1928, the remainder in 1929. A total of 15 samples were received from Austria, Czechoslovakia, Roumania, Jugoslavia and Russia, and 59 different varieties were received from the United States: 29 from Kansas, 8 from Minnesota, 10 from Ohio and 9 from Washington. Of the American wheats 48 were winter wheats, 11 were spring wheats, and one was durum. Canada was represented by 8 Manitoba No. 1 to No. 3 wheats of the 1927 and 1929 crops, Argentine by 5 samples (Bahia Blanca, Barusso, and Rosafe).

The moisture content of the samples as received varied from 9.3% to 14.1%, which limits have changed until at the beginning of the experiments the moisture range was from 10.8% to 12.4%. At the end of the experiments the moisture content of the unground wheats showed a maximum difference of 1.27%.

The moisture content of the 286 samples investigated has been tested under exactly the same conditions as described above, and it fluctuated from 11.87% to 12.73% (average 12.28%), the greatest deviation having been 0.86% (—0.41 to +0.45). According to these data but slight differences have appeared in the hygroscopicity of the wheat samples. In the instance of 90 out of 100 the maximum difference in the moisture content was 0.68%; half of the wheats showed a range of 0.29%. The results are shown in Table I. The last column represents the average amount of protein calculated on 12.5% moisture basis.

TABLE I

Moisture Content of Wheats at 65.3% Relative Humidity

Moisture	Number of Wheat Samples Examined	Per Cent of Total Samples	Protein Nx5.7
%			%
12.1	18	6.3	12.61
12.2	27	9.5	12.60
12.3	36	12.6	13.01
12.4	24	8.4	13.22
12.5	57	19.9	12.63
12.6	43	15.0	12.70
12.7	46	16.1	12.40
12.8	29	10.1	12.67
12.9	6	2.1	11.20
Av. 12.5%	286	100.0	Ave. 12.64

On the 12.5% basis the relative humidity of the air was 65.3% at 20° C. which is equal to the vapor pressure of 35.8% sulfuric acid. Fairbrother gives for flour a relative humidity of 61.2%, while from Bailey's data (1920), related to 12.5% moisture content, 71.1% may be calculated.

For determining the relative humidity, glass vessels were placed between the samples, containing 1 cc. each of 34 and 37% sulfuric acid. From the change in the weight of the vessels the concentration was calculated, by which the humidity of the air in the chamber is characterized. This method proved to be more reliable than the measurement with the hygrometer.

The hygroscopicity can hardly be related to any of the other properties of the wheat. The specific gravity of 15 wheats showing the lowest moisture was 1.357; on the other hand samples of the highest hygroscopicity were of 1.350 specific gravity.

American hard wheats are characterized by 12.49% moisture content (12.12-12.81%), the hygroscopicity of soft wheats of the same country by the average moisture percentage of 12.52% (12.15-12.77%). No correlation was found between the baking value and the hygroscopicity.

Experiments were conducted to determine whether the hygroscopicity is due to varietal differences or to the effect of the soil and climate. As shown by the data obtained with wheat varieties bred for experimental purposes the moisture content varies with the variety:

			Moisture Per Cent		
			Range	Difference	Average
Nemetboly	1928	9 wheats	12.25 - 12.55	0.30	12.44
Fürged	1928	14 wheats	12.16 - 12.45	0.29	12.31
Fürged	1929	15 wheats	12.58 - 12.84	0.26	12.74

The hygroscopicity of different wheats of the same area (Fürged) changes with the year of the harvest:

	Moisture Per Cent		
	1928 Crop	1929 Crop	Difference
Bankuti 1201	12.39	12.73	0.34
Bankuti 178	12.38	12.58	0.20
Bankuti 118	12.45	12.76	0.31
Szekacs 19	12.29	12.84	0.55
Eszterhazi 18	12.21	12.78	0.57

The hygroscopicity of wheats of the 1929 crop grown on different areas shows considerable differences:

		Moisture Per Cent	
		Range	Average
Eszterhazi 18	18 samples	12.58 - 12.80	12.50
Eszterhazi 11	5 samples	12.49 - 12.86	12.65
Szekacs 19	6 samples	12.27 - 12.84	12.53
Szekacs 11	8 samples	12.16 - 12.72	12.40

Based on the data given above, it may be stated that the difference in the hygroscopicity of wheats is a result of the climatic and soil conditions and that this property is influenced only in a secondary way by the variety.

Table II represents the moisture contents of wheats of different origin determined under exactly the same conditions. In Hungarian wheats greater differences were found than in samples grown on different areas of the United States.

The hygroscopicity of the wheat is not influenced by loss or gain of water. Wheat having been dried to a moisture content of 6% or moistened to 25% showed no change of the hygroscopic

TABLE II

HYGROSCOPICITY OF WHEATS GROWN IN DIFFERENT COUNTRIES

Country	Number of Wheat Samples Examined	Moisture Per Cent		
		Average	Minimum	Maximum
Hungary	200	12.50	12.09	12.95
Other countries of Europe	14	12.65	12.12	12.90
U. S. A.	59	12.50	12.12	12.81
Canada	8	12.39	12.28	12.73
Argentine	5	12.33	12.26	12.48

value. On the contrary the same wheat mixed up together in dry and wet state does not reach the same moisture content, as the gain of water as shown by Zsigmondy (1911) depends on and varies according to the diameters of the capillaries, the latter being larger when taking up water. As a consequence a higher vapor pressure has to be taken into consideration when gels are gaining water than when losing the same (hysteresis). This phenomenon accounts for the maximum deviation of 1.23% found, instead of 0.86% when the ground samples were placed in the same closed chamber for four weeks. Samples containing moisture ranging from 6% to 20% showed after four weeks a deviation of 0.5 to 0.6%. The hygroscopicity cannot, therefore, be characterized by direct determination of the moisture content.

Summary

The hygroscopicity of 286 wheat samples of Hungarian and foreign origin was determined to show the deviations in the moisture content when the samples were stored under the same conditions. Ground wheat samples weighing 2 g. which were spread on a surface of 25 cm² showed a maximal deviation of 1.23% when stored for four weeks in the same closed chamber. When the hysteresis was eliminated by preparing samples of a moisture content of 12% and 13% the greatest difference was 0.86%, the deviation from the average being from −.41% to +0.45%. In 90 per cent of the samples the maximum deviation was 0.68+; while 50 per cent of them deviated only 0.29%. For the moisture basis of 12.50% the corresponding value of the relative humidity was 65.3% at 20° C.

The differences in the hygroscopicity of wheat are caused by climatic and soil conditions. The influence of the variety is of subordinate importance. No changes are observable in the hygroscopicity whether the wheat is losing or absorbing water.

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THE FERMENTATION PERIOD OF NORTHWEST AND PACIFIC NORTHWEST FLOURS AS INDICATED BY CARBON DIOXIDE PRODUCTION AND DOUGH EXPANSION[1]

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In his monograph, "The Chemistry of Wheat Flour," Bailey (1925), discusses factors which have been found to correlate more or less with the aging of flours and comments to the effect that other changes not yet detected or measured may accompany the aging process. He also discusses Cobb's (1908) hypothesis which relates aging to an increase in fermentability.

In 1924 Bailey and Johnson suggested a method for the measurement of the fermentation period. In a study of several flours they showed that a clear flour produced more carbon dioxide than a hard spring wheat patent. However, a greater amount was lost from the dough, and the accelerated loss rate began earlier in the fermentation period in the case of the clear than in the case of the hard spring wheat patent. The time at which this change in rate occurs is suggested as a measure of the optimum fermentation period. The dough volume of the patent was a trifle larger. The method was used by Johnson and Bailey (1925) to study the gas retention of doughs and by St. John and Bailey (1929) during an investigation of the effect of adding dry skim milk to doughs and to bread. Comparing the results on hard spring wheat patent flour in the latter paper with those obtained by Bailey and Johnson (1924) it appears that the total gas production, dough volume, and carbon dioxide loss are somewhat larger in one of these flours than in the other.

The present study deals with two series of flours of different origin, each series including a number of different types of flours. The nature of these flours together with certain data on their composition is indicated in Table I.

Flours 1 to 9 are from the Pacific Northwest while the remainder are Middle Western flours.[2] The different patent flours were milled from different wheat blends and at different times.

The method and apparatus used were described by Bailey and

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[2] We are grateful to T. R. James, Chemist of the Sperry Flour Co., Spokane, Washington, for furnishing the Washington flours and to Dr. R. C. Sherwood, formerly Director of the State Experimental Mill, Minneapolis, Minnesota, for the Minnesota Flours. These men also furnished a part of the analytical data in Table I for which we express our thanks.

Johnson (1924), and with modification by St. John and Bailey (1929).

Pacific Northwest (Washington) Flours

Figure 1 shows a comparison of patent flours milled from different samples of Montana spring wheat. It is apparent that there is an increase in total gas production from short, through medium, to long patent. Likewise there is an increase in volume of dough expansion of the long patent over the others in spite of the greater carbon dioxide loss. Thus the increased volume of gas produced

TABLE I

DATA ON FLOURS USED

No.	Type	Protein	Ash	pH
		%	%	
	Pacific Northwest (Washington)			
1	Short Patent Montana Spring	11.7	0.38	5.5
2	Medium Patent Montana Spring	12.3	.41	5.7
3	Long Patent Montana Spring	12.8	.45	5.7
4	Clear from No. 1	14.5	.70	..
5	Clear from No. 2	16.0	.95	5.8
6	Clear from No. 3	17.0	1.20	5.7
7	Medium Patent from Hard White	11.0	.41	5.7
8	Medium Patent from family blend	10.3	.39	5.6
9	Long Patent from pastry blend	7.7	0.45	5.8
	Northwest (Minnesota)			
44	Medium Patent	13.1	0.43	5.6
45	Straight	13.5	.48	5.8
46	1st Clear	15.1	.61	5.8
47	2nd Clear	14.3	1.21	5.9
67	Medium Patent Unbleached	13.6	..	5.8
66	Straight Unbleached	13.9	..	5.9
64	1st Clear Unbleached	18.1	..	5.9
65	2nd Clear Unbleached	18.0	..	6.0
113	Patent Unbleached (Medium)	16.2	..	5.8
114	Straight Unbleached	14.9	..	5.8

was partly used in increasing the volume of dough and a part of it was lost. In the case of the medium and long patent the time required for the dough to reach a point where the rate of carbon dioxide loss accelerated rapidly was somewhat shorter than in the case of the short patent. This time was 120 minutes for the medium and long patent and 140 minutes for the other flours. These measurements were made from 20 to 35 days after the flours were milled. The loaf volumes of the bread baked from these three flours were very nearly the same.

Clear flours were taken from the same wheat blends from which the above patents were milled. The dough expansion of the

clears corresponding to the medium patent flour is the same as that flour, while it is a trifle less for the clear corresponding to the long patent. The loss of carbon dioxide from the clear flour doughs commenced at 120 minutes, the same as for the corresponding medium and long patents. The loaf volume of the clear flours was

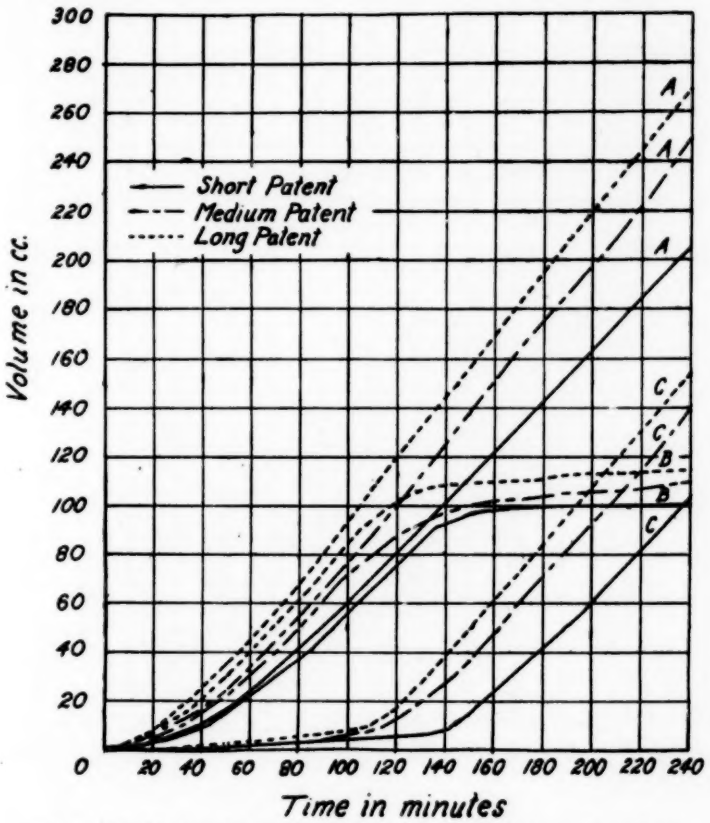

Fig. 1. Washington Patent Flours milled from Montana spring wheat.
Curves A—Total gas production
Curves B—Volume of the dough
Curves C—Loss of carbon dioxide from dough

a trifle less than that of the corresponding patents. There seems to be no relation between the per cent of protein in these flours and either the loaf volume or the fermentation since the amount of protein in the clears is decidedly above that in the patents. Neither does the H-ion concentration show any relation since the pH is practically the same for these flours.

Three other Pacific Northwest patents were studied, two medium patents from Hard White and a family blend flour. The

third was a long patent pastry blend. The results on the latter two are illustrated in Figure 2. The total gas production of the first two was the same as the long patent from Montana spring wheat. The dough volume of both was greater than the Montana Spring, that from the Hard White being a little greater than that from the

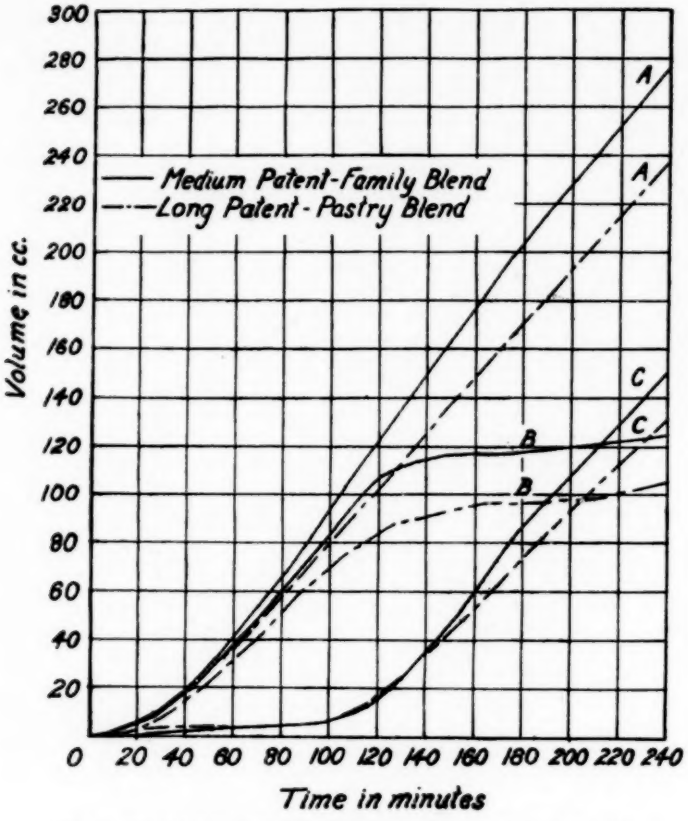

Fig. 2. Washington Patent Flours, Pastry and Family Blends. Curves A, B, and C same as Figure 1.

family blend. In the case of the long patent pastry blend, however, the total gas production was less, being equal to the medium patent Montana spring wheat flour. The dough expansion of this flour was the same as the short patent Montana spring wheat flour. The time at which gas loss accelerated was 120 minutes for all three of these patents. Here again there is no relation between this factor and loaf volume and the data on protein and pH. The only possible exception is in the case of the pastry flour where both the loaf volume and the per cent of protein are lower than the others.

In all of the measurements discussed up to this point the work has been done less than 60 days after the wheat was milled, ranging from this down to 20 days.

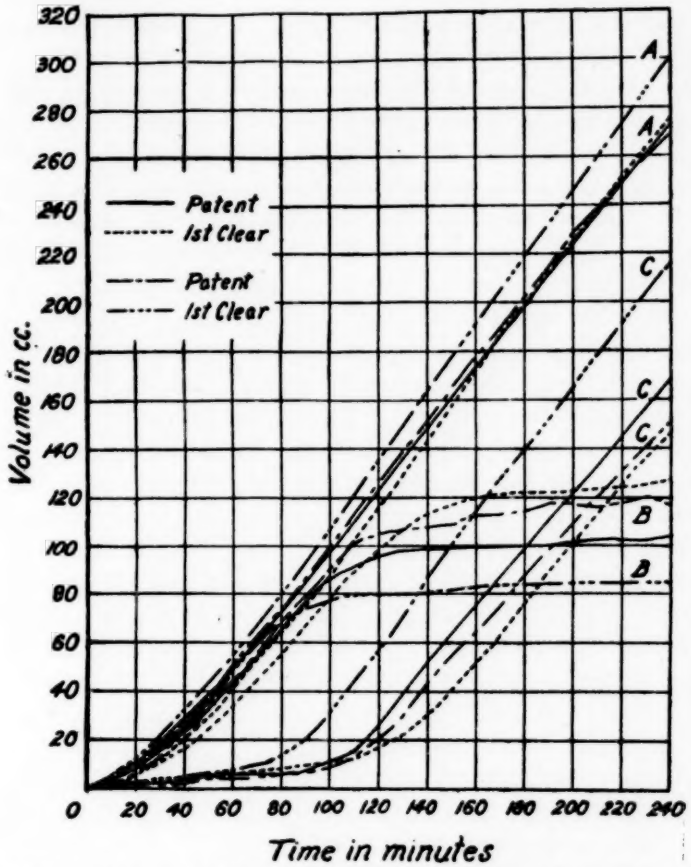

Fig. 3. Minnesota Patent and Clear Flours from two different wheat blends.
Curves A, B, and C same as Figure 1.

Northwest (Minnesota) Flours

In studying the data on the Minnesota flours it should first be noted, on the basis of later discussion, that these measurements were made on flours which had aged somewhat more than the Pacific Northwest flours, the time after milling ranging from 50 to 85 days.

The patent flours in this series were 80% patent spring wheat. The total gas production of these flours (See Figure 3) was the same as the long patent of the Pacific Northwest series (See Fig-

ure 1). The dough volume was the same as the long patent for two of them while for the third it was less and equal to the Pacific Northwest short patent. With the Minnesota flours the time elapsing before the carbon dioxide loss accelerated was about the same as the western flours, the break in the carbon dioxide loss curve occurring at about 120 minutes for all three of these patents. Upon studying the data for the straight grade flours from the same wheat blends as the above patent flours we find almost identical results with regard to total gas production and dough volume. In one instance the total gas production of the grade was slightly below the corresponding patent. The break in the curve for carbon dioxide loss also come at about the same time as for the patents.

A study has also been made of the first and second clear flours from two of the same wheat blends from which the above patent and straight flours were taken. Again the total gas production for all four of the clears was practically the same as for the patent and the straight grade flours (Figure 3). Some variation is found, however, in the volume of the dough from the clears. One of the first and one of the second clears gave a dough volume larger than any of patent or straight Minnesota flours and equal to the dough volume of the Western medium patent from hard white wheat. On the other hand, one of the second clears gave a dough volume equal to the smallest so far described, that of one of the Minnesota patents and the Western short patent. One of the first clears gave a smaller dough volume than any of the flours studied, (Figure 3) although the volume of gas production was nearly equal to the largest obtained. This means of course that the loss of carbon dioxide was greater than for any other flour studied. (Figure 3.) Coincident with these facts it is noted that the acceleration of carbon dioxide loss began at 90 minutes, which is the earliest of any of the flours reported upon here. A study of these results on the Minnesota flours in comparison with the data for protein and H-ion concentration shown in Table I does not show any relation.

Relation of Fermentation to Aging

Another interesting observation comes from additional data obtained upon these flours. After the data just reported were obtained additional measurements were made upon certain of the samples. The age of the flours at the time of this second series of measurements varied from 135 to 200 days. A third measurement was made on several of the flours 30 to 40 days after the second one.

In the case of the western flours the second series of measurements was made 120 to 140 days after the first. With all of these flours there was an increase in carbon dioxide production when the determinations were made at the later date. (Figure 4.) With the patent flours the total carbon dioxide produced was practi-

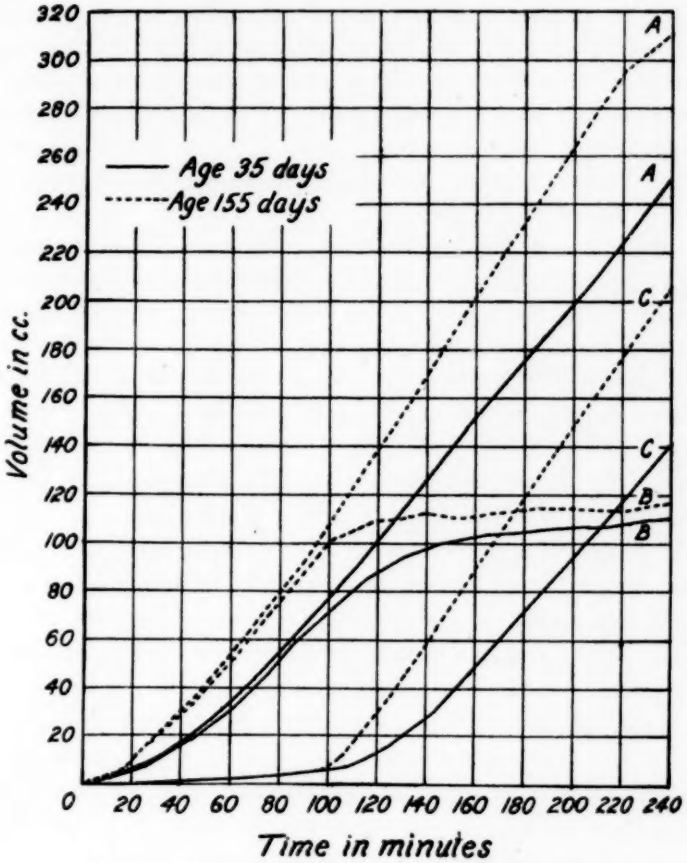

Fig. 4. Washington Medium Patent at different ages. Curves A, B, and C same as Figure 1.

cally the same for all three and was greater in volume throughout the period than the amount produced by the long patent at the time of the first measurement (Figure 1). The dough volume of the short and the medium patent was greater at the time of the second measurement although the extent of the increase was not as great as that of the total gas production (Figure 4). With the long patent the dough volume was decidedly less. The time at which carbon dioxide loss accelerated was earlier for

all three patents, being 110 minutes in comparison to 120 and 140 minutes in the first series.

A second measurement was made on only one of the western clear flours. The total gas production was a little greater but the dough volume was the same at the time of this later measurement. The time of acceleration of the carbon dioxide loss was the same.

With the family blend medium patent both gas production and dough volume were somewhat greater at the time of the second measurement. With the long patent pastry blend there was a decided increase in both the volume of carbon dioxide produced and in the volume of the dough. With both of these patents the accelerated loss of carbon dioxide began 10 minutes earlier at the time of the second measurement.

The Minnesota patent flours (medium) showed a slightly greater gas production but the dough volume was greater with only one of these three flours, the short patent, and with medium patent it was less. The time taken for the dough to reach its maximum volume was the same in all of these cases. Subsequent measurements were made on only one clear flour. This one showed an increase in gas production, but no increase in dough volume at the time of the second measurement. The time required to attain maximum dough volume was twenty minutes less.

A third measurement was made in several instances. On two of the Spokane patent flours the gas production was less while the dough volume was the same with one and less with the other. In the case of the Minnesota patent flours the carbon dioxide production increased while the dough volume increased slightly in the case of only one flour. The one clear flour studied showed no increase in gas production and a decrease in dough volume. The time required for maximum dough volume was the same for all instances when a third measurement was made as that obtained for the second measurement.

Discussion and Summary

In comparing the different flours there does not seem to be any consistent trend in the results. Considering the patents we find some relation between fermentation and percentage extraction in the case of the Washington flours, but on the other hand the different Minnesota patents give about the same results by this method. It will be recalled that the latter are all spring patents milled from different wheat blends. In this connection we should

recall that there was some variation between the spring wheat patent reported upon by Bailey and Johnson (1924) and the one

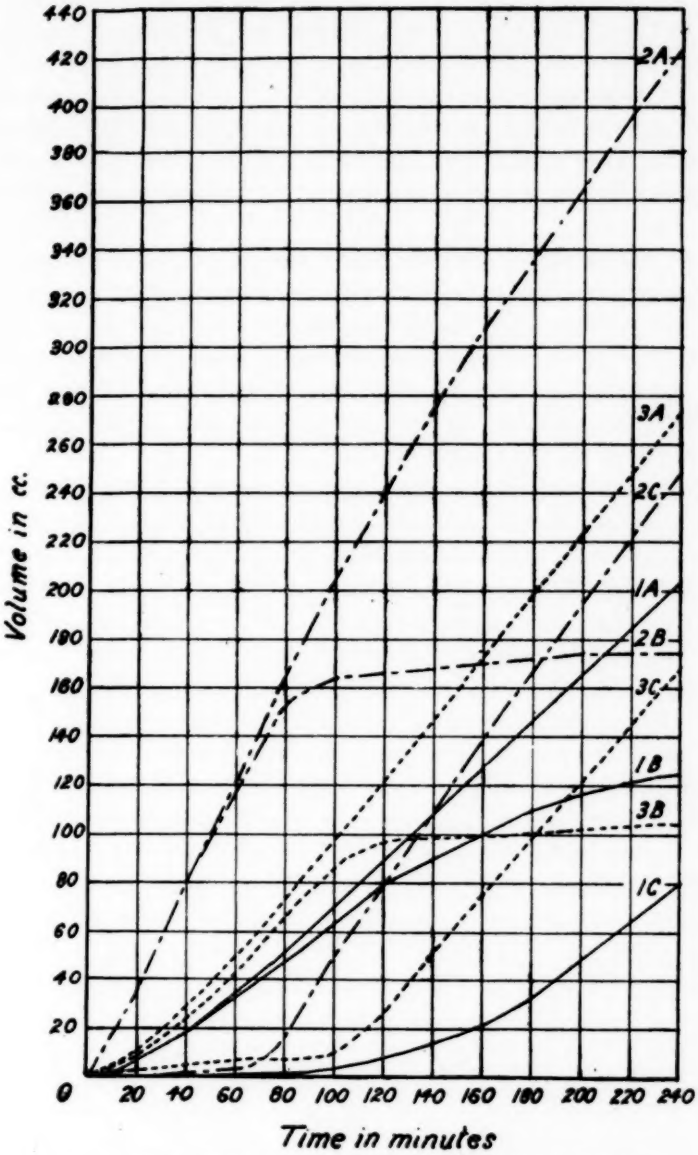

Fig. 5. No. 1—Flour studied by Bailey and Johnson (1924).
No. 2—Flour studied by St. John and Bailey (1929).
No. 3—Flour studied by St. John and Hatch (1930).
Curves A, B, and C same as Figure 1.

studied by St. John and Bailey (1929). In Figure 5 we show a comparison of these results with our own on a Minnesota spring pat-

ent.[2] This shows at least as great a variation between the spring wheat patents produced in the same region in different seasons as was found between different types of flours in the comparisons shown in this paper on flours from two different regions.

The results on the clear flours do not show any marked variation from the corresponding patent taken from the same wheat blend. In several cases the results for the clear and the corresponding patent were practically the same. The same is true for the straight grade flours and holds for both the Minnesota and Washington flours.

The measurements made after the flours had further aged suggest that there is a definite effect of age of flours on the fermentability of the dough as shown by this method. It is not clear whether this aging factor continues to be operative or exists only during the first few (4 to 6) months after the flour is milled. These results strengthen Cobb's (1908) hypothesis that there is a relation between aging and fermentability.

The results reported in this paper do not indicate any relation between the protein percentage or the H-ion concentration of the flours and the fermentation period.

In view of the fact that we have shown (1) that the fermentability of doughs from one type of flour from the same region may vary from year to year, (2) that different types of flour from the same wheat blend may show practically the same fermentability, and (3) that there is an aging factor in the fermentability of flour doughs, it would appear that the greatest usefulness of this method of studying fermentability would be to determine the effect of the addition of ingredients incorporated into the dough upon the fermentation period of an individual flour at any one time as illustrated by the work of St. John and Bailey (1929), and others.

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[2] Since Bailey and Johnson used dough equivalent to 50 g. of flour while we used 40, their results have been calculated to a 40 g. basis for the comparison shown in Figure 5.

A STUDY OF THE PROTEOLYTIC ENZYMES OF MALT PREPARATIONS

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It is generally recognized that the stability of bread dough depends upon a number of complex factors, and numerous researches have been concerned with the nature and magnitude of the effect of these several factors. Recent studies seem to indicate that one of the most important of these problems is to maintain a fairly constant concentration of fermentable sugars in the dough. It is also believed that the gas-retaining capacity of a dough is influenced by the activity of proteolytic enzymes. The source of these enzymes has been attributed to the flour, to the yeast, and to malt preparations used to increase the diastatic activity of the dough.

The literature of enzymes associated with flour, yeast, and other dough constituents which may be active in a fermenting dough has already been reviewed at some length in several contributions from these laboratories, and particularly by Rumsey (1922), Olsen and Bailey (1925), Cairns and Bailey (1928), Grewe and Bailey (1927), and Bailey (1925). In general it appears that flour contains active proteolytic and saccharogenic enzymes. Relative activity of these enzymes appears to increase in progressing from higher to lower grades of flour. Their activity is also greater in flours milled from sprouted or germinated wheat. Normal intact yeast cells probably do not effect any substantial proteolysis of the gluten proteins. On the other hand, it is possible that yeast cells are dying in appreciable numbers in an ordinary bread dough, and that these dead cells may contribute active proteases which are free to attack the proteins present, including gliadin and glutenin. Active (known in the trade as "diastatic") malt extract may also contribute proteases as well as diastase to the dough in which it is incorporated.

Experimental

Available data appear to indicate that proteases are apt to play an undesirable role in bread doughs; at least it is evident that the addition of preparations containing active proteases must be carefully regulated. Certain investigators have attributed the poor

[1] Paper No. 1011, Journal Series, Minnesota Agricultural Experiment Station.

quality of some of their breads to the proteolytic activity of the diastatic malt extract used. In view of the fact that the stability of bread dough appears to be determined in large measure by the maintenance of a fairly constant concentration of fermentable sugar in the dough, the following study was undertaken to determine the relative significance of the proteolytic and amylolytic enzymes of diastatic preparations used by the baking industry.

The problem may be separated into four main divisions: first, the removal of proteases from malt preparations; second, a comparison of proteolysis effected by malt preparations of medium and of high diastatic activity; third, the diastatic activity of malt preparations from which the proteases have been removed; and fourth, the relationship between proteolysis and comparative baking values of malt preparations.

Methods and Materials

Marston (1923) called attention to the fact that certain water-soluble compounds which contain the azine nucleus, such as safranine, will completely precipitate proteolytic enzymes from aqueous solutions, and that the azine precipitate retains proteolytic activity, but shows no diastatic activity. He believed that there was a direct combination of the enzyme with the azine nitrogen, and that the proteolytic activity of the azine compound depends upon the conditions that most favor dissociation.

It has long been known that proteolytic activity is responsible for hydrolytic changes which increase the proportion of simpler nitrogenous compounds which can be fractionated by the use of certain reagents. Two different methods were used in an effort to determine quantitatively the change in nitrogen distribution due to hydrolysis: (1) Sørensen's formol titration method, which is a direct measure of amino-acid nitrogen formed, and (2) Rittenhausen's copper hydroxide method in which the copper hydroxide precipitates out all the nitrogenous compounds down to the peptide and amino acid stage.

In the Rittenhausen (1872) method as modified by Blish (1918), and later by Olsen and Bailey (1925), 50 cc. of a flour suspension was measured into a volumetric flask. To this was added 20 cc. 0.2N sodium hydroxide and a few drops of phenolphthalein indicator solution and sufficient 0.2N copper sulfate to effect a change in color from blue to green. The solution was then made up to 100 cc., filtered, and an aliquot part used for the determination of non-protein nitrogen. This was determined by the

Gunning modification of the Kjeldahl method. Determination of total nitrogen in an equivalent quantity of the flour suspension was made at the same time.

The flour suspension was made by adding 20 parts of toluol water to 1 part of patent flour. The mixture was shaken every fifteen minutes for two hours, allowed to stand 30 minutes, and then filtered.

In the Sørensen (1908) formol titration method, 50 cc. of flour suspension to which had been added a few drops of thymolphthalein indicator solution, was titrated to a faint blue color with 0.1N sodium hydroxide. To this was added 10 cc. of 40 per cent formaldehyde solution which had been previously neutralized with dilute alkali, and the solution again titrated with 0.1N sodium hydroxide. Since the colorimetric method could not be used with flour extracts to which safranine had been added, an electrometric titration method was employed. Solutions were titrated to an H-ion concentration equivalent to pH 9.3, the point at which a faint blue color was produced in the untreated flour extract with thymolphthalein solution as an indicator, and also the point at which a faint pink coloration resulted with phenolphthalein solution as an indicator.

Through the collaboration of the American Diamalt Company we were supplied with two diastatic malt preparations which were used in the following experiments. One of these preparations, designated as "Diamalt Special," is an extract of medium diastatic activity (75°-80° Lintner); the other, designated as "Diastafor," is an extract of high diastatic activity (300° Lintner). The latter preparation, according to Collatz (1922), "showed evidence of an abnormally high proteolytic activity."

Removal of Proteases from Malt Preparations

As a preliminary test, 200 cc. of a 1% solution of pepsin was treated with an equal volume of 0.5% safranine solution. The resulting precipitate was allowed to flocculate 30 minutes, and the mixture centrifuged 20 minutes at high speed. The residue was washed with 0.5% safranine solution and the excess dye removed by six successive washings with absolute alcohol. It was then washed with ether and dried at 40°C. The azine precipitate was added to a flour suspension and digested 48 hrs. at 37°C. Using the Sørensen formol titration procedure it was possible to demonstrate a definite proteolysis in the mixture. Such proteolysis was not effected when an equivalent quantity of the supernatant liquid

resulting from the treatment of a pepsin solution with safranine was brought in contact with a like flour suspension.

The above experiment was repeated using a dilute solution of malt extract instead of the pepsin solution. To 200 cc. of a 2% malt extract solution was added an equal volume of 0.5% safranine solution. The resulting precipitate was separated and added to a flour suspension and digested 48 hours at 37°C. The non-protein nitrogen was determined by the Sørensen formol procedure and also by the copper hydroxide method. The addition of the azine precipitate to a flour suspension effected a material increase in the non-protein nitrogen content of the solution, but the addition of an equivalent amount of the supernatant liquid resulting from the safranine treatment to an equal volume of flour suspension did not effect an increase in non-protein nitrogen.

A Comparison of Proteolysis Effected by Malt Preparations of Medium and High Diastatic Activity

The experiments with malt extract were repeated to determine the rate of proteolysis effected by malt preparations of medium and high diastatic malt extracts. In previous experiments it had been observed that the greatest protein cleavage resulted if the freshly precipitated azo-enzyme complex was added to the flour suspension, and that more consistent results were obtained when the supernatant liquid from the precipitate was filtered before adding it to the flour suspension. The procedure was then modified as follows: after decanting the supernatant liquid the azo-enzyme precipitate was washed with a 0.1% safranine solution in the centrifuge, and then added to the flour suspension. The non-protein nitrogen was determined by the Sørensen formol titration method because it is the more rapid method and it seemed better suited to the measurement of proteolysis in flour suspensions than the copper hydroxide method. A series of tests was made in which the increase in non-protein nitrogen produced by the action of a medium diastatic malt extract on a flour suspension was compared with the increase of non-protein nitrogen produced by the action of a high diastatic malt extract on a like flour suspension during the same time and under identical experimental conditions.

Diastatic Activity of Malt Preparations from Which Proteases Have Been Removed

Two gram samples of wheat starch were weighed out and

transferred to 200 cc. Kohlrausch flasks; 50 cc. water was added to each sample, and the flasks, loosely stoppered, were then placed in a water bath for 30 min. at 100°C., cooled to 40°C, and the solution adjusted to pH 5.0 by adding orthophosphoric acid to the appearance of a pink color with methyl-red solution as an indicator.

To each sample of prepared starch was added 10 cc. of a 2% solution of malt extract. The flasks were closely stoppered and placed in a water bath for 2 hrs. at 40°C. The flasks were gently shaken at 15 min. intervals. At the end of the digestive period Rumsey's method (1922) as modified by Sherwood and Bailey (1926) was followed in determining the diastatic activity of the malt preparations. The starch solutions were diluted to approximately 175 cc. and clarified by adding 3 cc. of 15% sodium tungstate ($Na_2WO_4 .2H_2O$) solution. The solution was acidified by adding 0.8 cc. dilute sulfuric acid (concentrated, diluted 1:1) to pH 2.0 as indicated by a pink color produced with 5 or 6 drops of an aqueous solution of thymol blue (0.04%). This clarification stopped enzymatic action immediately and precipitated the proteins. The solution was then made to a volume of 200 cc., centrifuged, and 50 cc. of the clear supernatant liquid was measured out into a beaker and neutralized with sodium hydroxide solution for the determination of reducing sugar. The Quisumbing and Thomas (1921) method was used in the sugar determination, and the reduced copper was weighed as cuprous oxide.

A blank determination was made in a similar manner to correct for the original sugar content of the solution. In this blank determination the clarifying agents were added immediately after the addition of the malt extract.

The above experiments were repeated using 10 cc. of 2% malt extract solution from which the proteolytic enzymes had been precipitated by safranine.

The Relationship Between Proteolysis and Comparative Baking Values of Malt Preparations

Baking tests were made in which varying amounts (0.25, 0.50, and 0.75% respectively) of medium diastatic malt extract ("Diamalt Special") were added to the following bread formula: hard wheat flour, 325 g.; sugar, 10 g.; salt, 5 g.; yeast, 10 g.; Crisco, 7 g.; distilled water, 195 cc.

Baking tests were made in which like quantities (0.25, 0.50, and 0.75% respectively) of medium diastatic malt extract ("Diamalt Special") were dissolved and then treated with an equal vol-

ume (25 cc.) of 0.5% safranine solution. The resulting azo-enzyme precipitates were separated and the supernatant liquid from each substituted for a portion of the water in the above bread formula.

A series of tests was then conducted to determine whether or not the presence of safranine in the dough had any substantial effect upon bread qualities aside from color. Differences observed were of small magnitude, and accordingly all the other tests were referred to the "safranine control" which contained the same dosage of safranine as was used in removing the proteases from the diastatic malt extract.

The baking tests were then repeated, using the same quantities of high diastatic malt extract ("Diastafor") instead of the medium diastatic malt preparation.

When 0.5% medium diastatic malt extract was added to the bread formula, it was necessary to reduce the fermentation period (2 hrs. and 45 min.) by 10%, and a reduction of 15% was necessary when 0.75% was used. When like quantities of high diastatic malt were added, it was necessary to reduce the fermentation period 20 and 30% respectively. When 0.5% or more of the high diastatic malt extract was added it was necessary to reduce the proof period (normally 1 hr. and 5 min.) by 10 min.

Results

Flour suspensions treated with malt preparations showed a definite increase in the non-protein nitrogen content, but when the malt preparations had been previously treated with safranine there was no demonstrable increase in the non-protein nitrogen (see Table I). Only a very slight proteolysis occurred when suspensions of flour were digested at 37°C. for 48 hrs. That the protease content of high grade hard wheat flours is relatively low has been confirmed by the work of Cairns and Bailey (1928).

Malt preparations of high diastatic activity showed a higher protease content as evidenced by a greater degree of proteolysis in flour suspensions than malt preparations of medium diastatic activity. This confirms the observation of Collatz (1922) that malt extracts of high diastatic activity are characterized by a high proteolytic activity. (see Table I).

The freshly precipitated azo-enzyme complex showed more active proteolytic properties than the preparations that had been previously washed and dried. This difference may be due to partial inactivation of the enzyme by the washing and drying process or it may be due to the difference in solubility of the two prepara-

tions. It requires considerable time to dissolve completely the dried azo-enzyme precipitate in the flour suspension, but the freshly precipitated preparation goes into solution readily.

TABLE I

PROTEOLYSIS OF MALT PREPARATIONS

Description of Preparation	Increase in 0.1N NaOH After Adding Neutral HCHO. cc per 10 grams Flour
"Diastafor"	
(1) 200 cc. Malt Extract (2%)	17.5
(2) Azo-precipitate from 200 cc. Malt Extract	25.5
(3) Supernatant Liquid from (2)	1.6
(4) Control (Flour Suspension)	1.5
"Diamalt"	
(1) 200 cc. Malt Extract (2%)	6.5
(2) Azo-precipitate from 200 cc. Malt Extract	7.5
(3) Supernatant Liquid from (2)	1.7
(4) Control (Flour Suspension)	1.6

Of the two methods used in measuring the rate of proteolysis in flour suspensions, the Sørensen formol titration method was the most satisfactory. This is in accordance with the findings of Cairns and Bailey (1928), who consider this method better suited to the measurement of proteolysis in flour suspensions than any other of the nine methods employed in their study of the proteoclastic activity of flour.

Malt extracts previously treated with safranine showed the same degree of diastatic activity as an equal quantity of the original extract. This confirms Marston's (1923) conclusions that diastatic enzymes are not precipitated by safranine. (See Tables II and III.)

The addition of malt preparations to doughs effected a material improvement in volume, grain and texture of the bread, but a much greater improvement was noted when the malt preparation had been previously treated with safranine to remove the proteases. This improvement was more marked with high diastatic than with medium diastatic preparations. The fermentation and proof periods are materially shortened by the addition of 0.5% or more of the malt preparations. The addition of malt extract to bread doughs in quantities ranging from 0.25 to 0.75% of the weight of flour in the dough effected a gradual increase in volume, but breads made with 0.75% high diastatic malt extract were inferior in grain and texture. Breads made with 0.5% malt extract showed an improvement in volume and grain and texture.

The addition of safranine solution to the bread formula with-

out the addition of malt extract produced a bread that was superior to the control in volume and texture. There is undoubtedly a precipitation of proteases of flour and yeast by the safranine, but since the azo-enzyme precipitate retains active proteolytic activity, it is difficult to explain the improvement noted in these breads. It may be that there is a certain amount of agglutination of the azo-enzyme particles which reduces its range of activity to a certain extent. Whatever the explanation may be, it was quite surprising to find that the treatment of doughs containing such a small amount of proteases as are believed to be present in flours and yeast should show any improvement when treated with safranine.

The data from baking tests are summarized in Tables II and III.

TABLE II

SUMMARY OF RESULTS OF BAKING TESTS WITH MALT EXTRACT OF MEDIUM DIASTATIC ACTIVITY

	Loaf Volume	Grain	Texture
	cc		
Safranine Control	2010	97	98
0.25% "Diamalt Special"	1960	96	96
0.25% "Diamalt Special" +Safranine	2110	97	97
0.50% "Diamalt Special"	2060	98	98
0.50% "Diamalt Special" +Safranine	2120	96	97
0.75% "Diamalt Special"	2030	96	96
0.75% "Diamalt Special" +Safranine	2210	97	97

Fermentation period reduced 10% in the doughs containing 0.5% "Diamalt Special," and 15% in the doughs containing 0.75% "Diamalt Special."

TABLE III

SUMMARY OF RESULTS OF BAKING TESTS WITH MALT EXTRACT OF HIGH DIASTATIC ACTIVITY

	Loaf Volume	Grain	Texture
	cc		
Safranine Control	2010	97	98
0.25% "Diastafor"	1970	95	97
0.25% "Diastafor" +Safranine	2120	97	98
0.50% "Diastafor"	1980	96	94
0.50% "Diastafor" +Safranine	2190	98	99
0.75% "Diastafor"	2080	93	87
0.75% "Diastafor" +Safranine	2210	88	85

Fermentation period reduced 20% in the doughs containing 0.5% "Diastofor," and 30% in the doughs containing 0.75% "Diastofor."
Proof period reduced 10 min. in the same four series.

Conclusions

1. Safranine effects a substantial, if not a complete, removal of proteoclastic enzymes from wheat flour and malt extracts.

2. Very little proteolysis occurs in flour suspensions made from hard wheat patent and straight grade flours.

3. Diastatic malt preparations have a comparatively high pro-

tease content as evidenced by a material increase in non-protein nitrogen in flour suspensions treated with malt preparations.

4. High diastatic malt preparations have a higher protease content than malt preparations of medium diastatic activity.

5. The proteoclastic enzymes of malt preparations apparently effect a degradation of proteins and thus produce an inferior grade of bread if the malt preparation is used in sufficient quantity to materially improve the diastatic activity of the dough.

6. The proteases of diastatic malt preparations are precipitated by the use of safranine without any appreciable reduction of the diastatic activity of the preparations.

Summary

1. An active proteolytic preparation was obtained from the precipitate which resulted from treating diastatic malt preparations with safranine.

2. The copper hydroxide method and Sørensen's formol titration procedure were used to measure progressive proteolysis in flour suspensions. The two methods gave good checks, but the Sørensen formol titration method is less time-consuming than the copper hydroxide method.

3. High diastatic malt extracts showed a greater proteolytic activity than medium diastatic malt extracts.

4. Malt preparations treated with safranine effected a material increase in loaf volume, and some improvement in grain and texture. These improvements were more marked with malt preparations of high diastatic activity than with malt preparations of medium diastatic activity.

5. When more than 0.25% (of the weight of the flour) of medium diastatic malt extract was added to the bread formula it was necessary to reduce the fermentation period from 10 to 15%; and when more than 0.25% (of the weight of the flour) of high diastatic malt extract was added, it was necessary to reduce the fermentation period from 20 to 30% and the proof period 10 min. to prevent over-fermentation of the doughs.

Acknowledgments

The writers are indebted to the Fleischman Company for a Fellowship during the year 1926-1927 which made this study possible; to the American Diamalt Company for the malt preparations used and to C. C. Fifield, baking technician, for assistance in making the baking tests and scoring the breads.

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MILDLY TOASTED WHEAT GERM—A POSSIBLE MERCHANDISABLE TABLE CEREAL

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While associated with the cereal industry in the recent past the writer made some simple investigations with wheat germ with the purpose of developing a possible palatable table cereal of good keeping qualities and thereby permitting its merchandising in package form to the retail trade.

Wheat germ, a by-product of flour milling, is almost wholly disposed of as animal feeds. Its high mineral (4.5%), protein (30%) and lipin (10%) content, its food-energy value (3.8 calories per gram) and especially its outstanding potency in vitamins B, G

and E have won for it merited recognition as a valuable supplementary food. The partial diversion of a food of this potential nutritive value from animal feeds to human consumption would add a worthwhile contribution to the diet list of the nation. Apparently at least two characteristics have thwarted its having been launched heretofore in a commercial way on the market as a human food, namely, uncertainty in keeping qualities and questionable palatability.

Considerable of the wheat germ from modern flour milling can be obtained in a quite pure form with only a small proportion of broken flakes, bran and foreign material. The whole flakes have a pleasing appearance. The flavor, however, is raw, somewhat peculiar and leaves a slightly unpleasant after-taste. The keeping qualities are considered uncertain.

Some simple investigations were undertaken during the first half of 1930 to determine a practical means for enhancing the palatability and the keeping qualities of wheat germ. In view of its unique nutritional values attainment of satisfactory keeping qualities and palatability would seem to make this material a good merchandising risk as a human food.

An excellent sample of germ was obtained from a prominent mill. Portions spread out on baking sheets were toasted in a gas oven with frequent stirring at various temperatures to different degrees of brownness. Under the conditions of the test 120–130° C. seemed to yield the best results in terms of flavor and color. Color was the best guide for judging the desired intensity of the toasting.

Germ toasted to a light brown was chosen as most acceptable on the basis of palatability. Such toasted germ has a pleasing nutty flavor and is almost lacking in rawness and after-taste.

The keeping qualities of this toasted germ were then put to test. Quart jars free from any odor were half filled with the sample. The glass lids were clamped on without the rubber gasket and the jars stored at a constant temperature of 50° C. The odor and flavor were noted daily for about 25 days. Both odor and flavor to great surprise remained sweet and pleasant throughout the period. Previous experience with the duration and temperature of this test using many cereals indicates that this germ would "stand up" under the usual conditions of storage of cereals for from one to two years or more. A portion of this toasted germ has been retained to learn its qualities after aging in a paper cereal carton at ordinary room temperatures. This sample, now about ten months old, is still "perfectly" good.

As a result of the tests it is the opinion of the writer that wheat germ toasted at fairly moderate temperatures (120–130° C.) to a light brown color is pleasingly palatable, has dependable keeping qualities, and has potential merchandising features as a human food that merit the attention of cereal manufacturers. No biologic tests were made of the vitamin factors present in the toasted germ. It is believed, however, that under controlled factory production conditions with proper equipment the toasting could be effected in two or three minutes, which it is reasonable to assume would not impair the vitamin content except for vitamin B. This latter vitamin factor would very probably not be seriously reduced in the short period of toasting. A rapid cooling of the germ should quickly check the deleterious action of the heat.

The toasted germ should serve as an appetizing and valuable vitamin supplementary food for contributing unique food values, eating qualities, and an attractive addition to salads, vegetable dishes, biscuits, breads, cakes, meats, desserts and other dishes of the American table.

The preparation of the toasted germ on a factory or production scale is not deemed to involve any serious problems. A slowly revolving drum-toaster maintained at a fairly moderate baking temperature should be practical for the toasting process. High temperatures may cause decomposition of the oil with untoward results although no experimental evidence was obtained.

It is the main purpose of this article to call attention to the palatability, pleasing and appetizing appearance, and the good keeping qualities of lightly toasted wheat germ. Any definite vitamin claims must rest upon experimental evidence obtained on the particular preparation.

A unique and entirely new application of the toasted wheat germ in a special self-rising flour is presented in the following article.

A TOASTED WHEAT GERM SELF RISING FLOUR —A POSSIBLE MERCHANDISABLE CEREAL

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In the preceding article "Mildly Toasted Wheat Germ—A Possible Merchandisable Table Cereal" the writer called attention to the potential merchandising possibilities of mildly toasted wheat germ as a table cereal and as a nutritionally valuable supplemental food to the average diet. Unquestionably such toasted germ can be advantageously used from both nutritional and palatability standpoints admixed with many common commercial and home prepared foods.

In the recent past before the writer was connected with the Committee on Foods he carried out some investigations for the development of a self-rising flour containing sufficient of such toasted germ to give baked products possessing characteristic, pleasing and different eating qualities from ordinary baked products. The particular flour-germ mixture, evolved because of its unique palatability and nutritional features, is believed to merit consideration for merchandising in package form to the retail trade. A brief outline of the investigations and the formula of the finally accepted self-rising flour and germ mix are presented below.

From previous experience with self-rising flours it was decided to use an 80% soft winter wheat patent flour matured with Beta Chlora (1½ oz. per barrel) and containing 1.5% baking soda with its neutralizing equivalent of proportioned sodium acid pyrophosphate and calcium acid phosphate, 1.6% salt, and 1.5% Cerelose (dextrose) as the basic materials for the experimental mixes for the baking tests of the investigation. Biscuits and plain white cake were baked in order to judge the mixes.

Pyrophosphate was chosen as one of the acid chemicals because of its effect on volume and form of biscuits and cakes. Especially good volume and level top or exterior outline are obtained for cakes leavened with baking soda and pyrophosphate only. The flavor, texture and grain, however, are not all that is to be desired. Calcium acid phosphate was also chosen as one of the acid chemicals because of its favorable influence on grain, texture, and flavor. Cakes leavened with baking soda and this phosphate only have an excellent texture, grain and flavor, lack somewhat in

volume, and have peaked or humped tops. Biscuits have a poor volume and close texture. A combination of these two acid chemicals, however, produces those baking features considered optimum for practical purposes and was therefore decided upon.

It first was deemed necessary to determine the respective ratios of baking soda to pyrophosphate and to phosphate which produce optimum bakes as judged by general results with biscuits and plain white cake. A series of baking trials using various ratios of these chemicals indicated the ratios of 100: 53.5 and 100: 73.8 respectively to be most favorable for the particular pyrophosphate and phosphate used. These ratios were adopted in all subsequent mixes.

A series of baking trials was next conducted in which various mixtures of the two phosphates were used. From the results, that particular mix was chosen as most favorable in which the pyrophosphate liberated 60% of the CO_2 and the phosphate the remaining 40%. These proportions were chosen for subsequent mixes.

Having obtained what was considered a superior self-rising flour mix with these leavening chemicals in the specified proportions the next step in the investigation was to determine the influence of incorporation of the toasted whole germ. Quantities of 50, 75, 100, 125, 150, 175, 200 grams of toasted whole germ respectively were substituted for flour in a series of batch mixes (1,000 grams total per batch). Mixes containing 125 and 150 g. of germ were chosen as most acceptable, the bakes of which were unexpectedly delightful and unique in flavor and considered equal in other respects to baked products made without germ. It should be mentioned here that ground germ gives entirely unsatisfactory results.

Variation of the salt content of the chosen mix was then observed, and 1.6 to 1.8% was favored. After deciding on this feature one additional ingredient, Cerelose (dextrose) was added to enhance the crust color of biscuits and slightly modify the flavor, the amount used being 1.5%.

The formula of the finally approved mix producing all sought-for qualifications follows:

850 g. 80% winter wheat patent flour
(1½ oz. Beta Chlora per bbl.)
125 to 150 grams toasted whole germ
15 g. baking soda
16.82 g. sodium acid pyrophosphate
8.13 g. calcium acid phosphate
16 to 18 g. salt
15 g. Cerelose

A number of different types of cakes baked with the approved mixture were all highly satisfactory.

The keeping qualities of the mix are excellent as evidenced by storage tests in closed mason jars at 120-130 F. for 25 days. No "off" odor or flavor developed.

Some apparent reasons why the proposed toasted wheat germ self-rising flour should deserve merchandising consideration may be summarized as follows:

(1) The wheat germ ingredient (12.5 to 15%) contributes a possible tenfold greater vitamin B, G and E value to the product than that found in whole wheat. Accordingly it may be classed among the rich vitamin foods. It is of course many times richer in vitamin value than the usual flour products.

(2) It produces highly pleasing tasty bakes with unique new and different characteristics which should win public acceptance.

(3) Its general adoption for merchandising would add value to wheat germ, one of the by-products of flour mills.

(4) The special leavening mix gives it excellent baking qualities.

(5) The Cerelose (dextrose) content gives well-colored biscuits, pie shells, etc.

(6) Cost of volume production should be very little more than that for the usual self-rising flour.

It is believed the addition of toasted wheat germ to flour for general baking purposes may deserve consideration for developing a new line of bakery goods with supplemented nutritional values and thereby tend to increase flour consumption to the benefit of the milling industry and at the same time raise the vitamin level of the average diet.

USE OF OXYGEN IN THE QUICK DETERMINATION OF ASH

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There is a decided demand among mill control laboratories today for a shorter method in the determination of ash. The search for this method has led to several deviations from the regular method of the A. A. C. C., both as to type of crucible used and means of combustion which are herein described.

Instead of the usual type crucible size 0-00 we are using a flat bottom silica capsule 1¾ in. in diameter and ½ in. deep. This capsule shortens the burning time approximately one hour, in that more surface of the flour is exposed to the oxidation and more of the bottom of the container is in direct contact with the heat on the bottom of the muffle.

By having the initial temperature of the furnace rather cool, approximately 800° F., leaving the door open during the burning-off period, and gradually increasing the temperature to about 1000° F., we avoid fusing the ash, another vexing problem in some types of flours.

In the application of oxygen to the burning of ashes two furnaces are used. The first, for the initial or burning-off period, is kept at a temperature of 800° F. with the small inspection holes in the door and back of muffle left open. The samples are allowed to remain in this furnace 40-50 minutes, or until the black mass starts to curl around the edges and shrivel toward the center of the capsule.

The ashes having reached this stage, they are introduced into the second furnace, maintained at a temperature of 1100° F., into which a small stream of oxygen is fed from a compressed cylinder through an Alsop chlorine regulator at the rate of 150 bubbles per minute.

This furnace is air tight and asbestos packing is used around the ⅜ in. iron pipe through which the oxygen is introduced. The rate of flow of oxygen should vary with size of furnace and number of ashes to be burned, but the ash should assume a reddish glow immediately upon being introduced into the oxygen.

The ashes are left in this furnace ¾ to 1½ hours, or until such time as it will take for them to assume a white or light gray color. They should be in one mass near the center of the crucible and of a light, flaky nature so they can be brushed out easily on the scale

pan with a stiff brush, as direct weighing is used entirely. Five gram samples are used on all determinations.

As correct temperatures are the most important item in the success of this method, pyrometers should be carefully checked with pyrometer cones and the correction applied.

Results by this method will check the A. A. C. C., official method, which ordinarily requires five hours to complete a determination.

Below are given some comparisons of our results and the averages on check samples sent out by the Pioneer and Northwest Sections of the A. A. C. C.

W. F. Mls.	Check Sample Averages
.432	.435
.444	.447
.412	.413
.530	.529
.490	.482
.404	.400
.472	.479
.774	.770
.472	.472
.470	.4697

By the above method a flour ash can be burned with oxygen to check the regular A. A. C. C. method in 1½-2 hours, thereby shortening the time consumed approximately 3 hours.

A FERMENTATION AND PROOFING CABINET GIVING LOW TEMPERATURE VARIABILITY [1]

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The tentative adoption of the Werner fixed baking procedure by the American Association of Cereal Chemists is a result of recognition of the fact that test baking is a scientific experiment that should be subjected to rigid control and standardization. Blish (1928) has pointed out many of the advantages of this method as

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compared with methods depending on the judgment of the individual operator. The mere adoption of the method, however, does not solve all the difficulties involved in experimental baking. One of the major problems encountered in this laboratory has been the control of temperature during fermentation and baking. The fermentation and proofing cabinet described in this paper was designed to reduce errors due to temperature variations, and to facilitate handling large bakes.

One of the advantages that early became apparent in the use of the fixed procedure was that it made possible a considerable increase in the number of tests per day, because all operations are controlled from a definite time schedule. With the variable fermentation method, it is usually considered that 12 to 20 loaves constitute a day's work for one man with unit equipment, whereas with the Werner method, 50 loaves per day is a relatively simple accomplishment. As the baking test is still considered the most reliable criterion of quality, the scale on which investigations may be carried out is determined by the baking capacity of the laboratory, and this is an important consideration with certain types of work such as area surveys, comparison of methods, variety testing and many other projects.

In the attempt to increase our baking capacity, some rather grave difficulties were encountered, and it is thought that the means taken to overcome them may be of interest to those engaged in similar work.

The baking method followed in this laboratory is similar to the standard procedure as outlined by the Committee on Baking Methods of the American Association of Cereal Chemists, except that low-sided pans are used in place of the tall pans, the absorption is varied to suit the flour, and machine mixing is used in place of hand mixing. The formula varies only in the use of 100 g. of flour on a 13.5% moisture basis instead of 100 g. on a 15.0% moisture basis, but this is of minor importance. Times and temperatures are as prescribed for the Werner procedure.

A Hobart mixer equipped with a small bowl and a particular set of hooks is admirably suited to this work. It has been found that machine mixing makes a dough that is initially more uniform in texture than one mixed by hand, and there seems to be some evidence that the machine-mixed doughs give larger loaf volume. The particular advantage of the machine mixing, however, lies in the fact that it leaves the operator free to attend to other matters, and it is by virtue of this fact that the number of tests per day per

man can be increased. According to our procedure, flours go to the mixer at regular 5 min. intervals. A minute is allowed for measuring and introducing the ingredients, and the dough is mixed for 4 min., using three different speeds. When the 22nd flour is placed in the mixer, the first dough is ready for the initial punching. While No. 29 is mixing, No. 1 is given the second punch, and No. 11 the first punch. This schedule is fairly simple if only 34 flours are to be mixed. Beyond that, it requires more speed and attention, for thereafter it is necessary to make a first and second punch and a panning during the 4 min. mixing period. If it is desired to extend the run to 47, another operation, namely placing a pan in the oven, is added to each 4 min. period, and beyond 52 one must, in addition to the foregoing, also remove a pan from the oven. This represents the limit, however, for if sufficient skill to handle this schedule beyond No. 52 is attained, the day's run need be limited only by the time at which one desires to finish. Single runs as high as 80 have been made. The times at which the various operations have to be performed are controlled by printed baking sheets. Carrying out such a routine successfully necessitates a high degree of concentration, freedom from interruptions, the elimination of unnecessary motions, as well as some little practice.

When a day's run exceeds 36 flours, it is necessary to provide space in the fermentation cabinet for 36 doughs, because the 36th dough is being panned while the 37th is being mixed. Thereafter one bowl and one space become vacant every five minutes. The necessity for having 36 bowls in the cabinet at one time led to our first difficulty. The fermentation cabinet in use was of a common type designed for about 12 half-gallon crocks, with two slatted shelves and heating elements in the bottom. When the 100 g. formula was adopted, we designed a bowl 5 in. in diameter, 5 in. high, with perpendicular sides and a concave bottom, made from fire-clay with a special glaze by the Ceramics Department of this University. It was possible to place 36 of these crocks in the fermentation cabinet, but the circulation of air was interfered with due to the close array on the shelves, with the result that those on the lower shelf were always warmer than those on the upper one. It seemed that the lower crocks were being unduly heated by direct radiation from the elements. In order to remedy this, the bottom of the cabinet was removed, the whole raised 6 in., and the heaters were placed down to the bottom. This made very little difference. A sloping baffle was then placed over the heaters and the warm air was forced to ascend a 2 in. space made by introducing a false

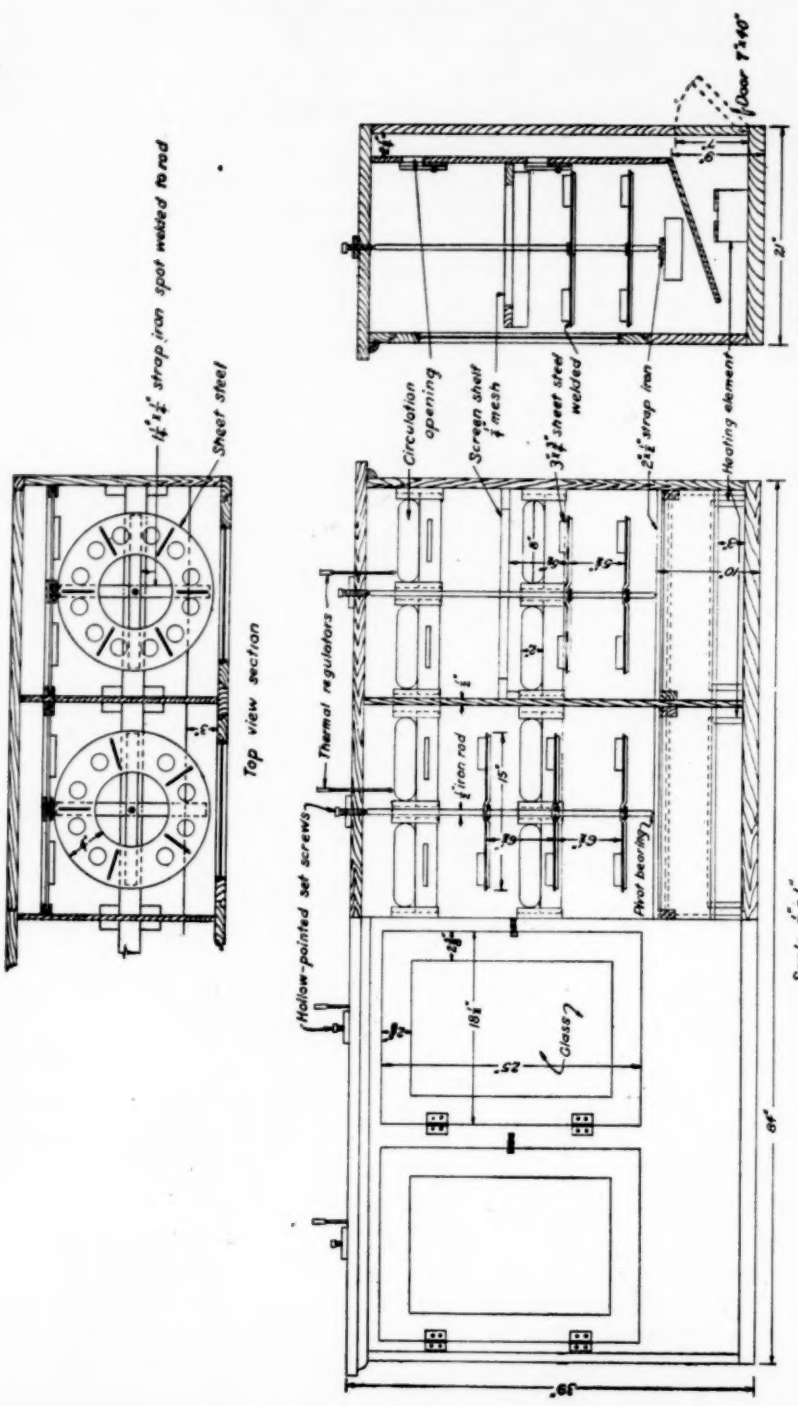

Fig. 1. Details of construction of the cabinet and revolving shelves.

back-wall of asbestos paper. This gave definite improvement, but there existed still a wide range of temperature differences longitudinally in the cabinet. A fan was then built into the cabinet. This gave a more equable air temperature, but it was found practically impossible to cover the crocks tightly enough to prevent drying of the doughs that were in the direct path of the air current, even when the humidity of the cabinet was kept high.

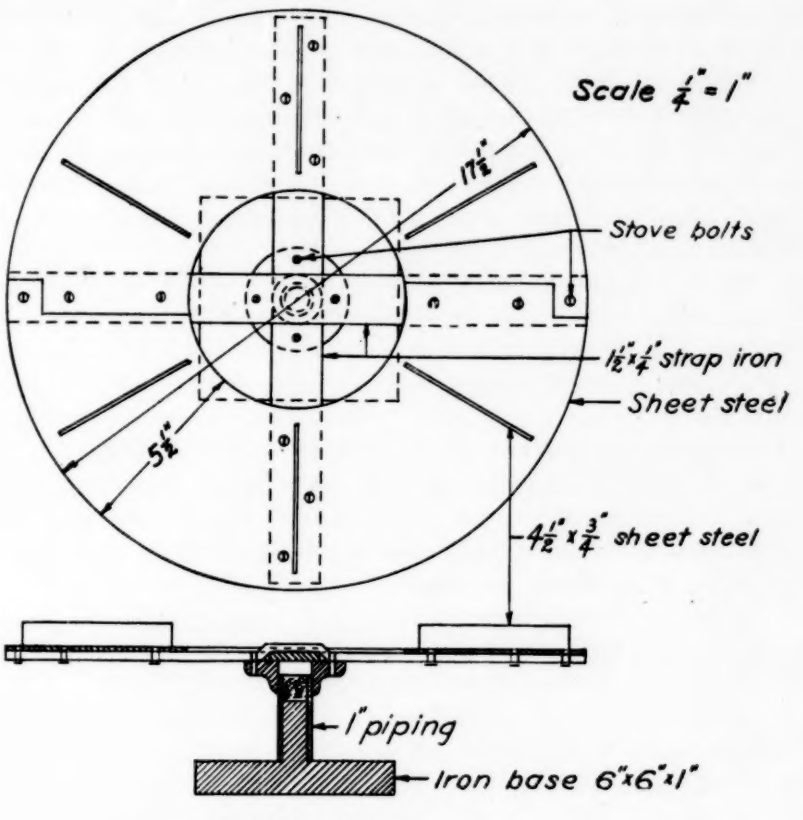

Fig. 2. Diagram of revolving shelf for the baking oven.

The principle upon which the cabinet was constructed seemed fundamentally unsuited to a schedule such as we were attempting to practice. The doors had to be opened so often that the convection currents were being continuously disturbed. It was thought that a series of small, independently heated and controlled cabinets would prove more satisfactory. Accordingly a new cabinet was constructed in our shops, a design of which is shown in Figure 1.

The diagram is nearly self-explanatory. Attention should be directed to the fact that the partition walls between the compartments extend to the bottom of the heater chamber and to the back of the outer rear wall. Each compartment therefore is a separate unit. The space below the sloping baffle, which will be referred to hereafter as the heater chamber, is completely lined with asbestos paper. Vents in the rear wall are shown at two different levels, but our experience has indicated that only the upper set is necessary. The lower vents are seldom opened. The screen shelf in the fourth compartment serves as a convenient support for the humidifier.

The doors shown in the figure are too large. If the cabinet is to be used with fixed shelves, it would prove more satisfactory to split the doors longitudinally. For the rotary shelves, a narrow door, not more than 8 in. wide, would be better. This would give ample space for handling the crocks, and would doubtlessly tend to decrease temperature fluctuations.

The heating elements consist of two strips of transite 18 in. by 2 in. wound with nichrome wire, mounted on legs 3 in. high. They are placed about 6 in. from the back of the heater chamber. One element in each compartment is connected in series with a deKhotinsky thermo-regulator. The others, wired in series, are controlled by a switch outside the cabinet, and are designed for use as continuous heaters. For low room temperature these heaters are left on continuously, and thus the automatically controlled elements can be of rather low heating capacity, thereby reducing temperature lag in the cabinet.

In the three compartments used for fermentation, flat pans of water are placed at the front of the heater chamber so that the downward air currents have to pass over them. In the proofing cabinet, proper humidity is maintained by means of a small Bahnson cigar-case humidifier. The temperature is checked by three 50° C. thermometers in each compartment.

To test the efficiency of the cabinet, runs of 50 loaves from one flour were made, during which the temperatures of the doughs in various positions were taken at the time of the first and second punches. It was found that no appreciable difference between top and bottom shelves existed, but that doughs in the corner positions had a tendency to vary by as much as 1° C. The upper vents in the false back wall had been placed to the outer edges expressly to ensure a good air circulation along the side walls, but apparently the opening of the doors interferred with convection currents.

Temperature differences had been observed previously be-

tween the outside and centre positions in the oven. It was thought that a contrivance to shift the doughs through a series of successive positions would obviate the errors arising from this cause, and for that purpose the rotary shelf shown in Fig. 2 was constructed.

The first rotary shelf was placed in the oven. It was simply and inexpensively made of two crosspieces of iron upon which was fastened a circular plate of sheet metal. To avoid having to tear down the oven, the shelf was made in two sections and bolted together after having been placed in position. The shelf, which provides places for six pans, is rotated by means of the pan tongs. Each time a loaf is put in the oven, the shelf is given a one-sixth turn. On a 5 min. schedule there are always five loaves in the oven and one vacant place. The sixth pan goes in the vacancy and the first loaf is removed, leaving a space for the seventh. By this means each loaf occupies precisely the same position in the oven for the same length of time as its predecessor. Aside from whatever advantage may accrue from this, the fact of having the pans at the door of the oven permits much more rapid handling; the oven door need be open for only a fraction of the time necessary in the ordinary way, and thereby temperature fluctuations are greatly reduced.

This device proved so convenient that similar shelves were installed in the fermentation and proofing cabinets. For the latter, a two-decked shelf with six places was made. By our schedule, eleven pans are in this cabinet at once. As the twelfth is put in, the first goes to the oven, and the shelf thus provides always one vacant place in front of the door.

For the fermentation cabinets, three shelves having five places each are rigidly mounted on a rotating vertical shaft with top and bottom bearings. This provides space for fifteen bowls in each compartment. The arrangement works out very satisfactorily because, due to the choice of a 5 min. interval and the fact that the last two fermentation periods are 50 and 25 min. respectively, the doughs that have to be punched in any one cabinet are always directly in line vertically. Thus when No. 11 is ready for the first punch, No. 1 is ready for the second punch, and when No. 6 is ready for the second punch, No. 1 is ready for panning. When any set of operations is completed, the shelf is given a one-fifth turn and the next two are brought in front of the door, so that no time is lost in trying to locate the proper dough.

There are two very distinct advantages of the rotary shelves for both oven and cabinets, namely, the doughs are kept away

from the corners, where the temperatures are most difficult to control, and the doughs to be handled are always at the door, thus reducing the time during which the doors have to be kept open. Moreover they may be constructed by any good blacksmith or machinist and installed at low cost.

To determine the temperature variability in the cabinet, temperatures of doughs were taken immediately before the first and second punches. The bowl was removed from the cabinet; a thermometer graduated to tenths was inserted in the centre of the dough, and the reading taken at the end of one minute. The results are shown in Table I. While no claim for absolute accuracy of

TABLE I

TEMPERATURE[1] OF DOUGHS IN VARIOUS POSITIONS IN THE CABINET AT THE TIME OF THE FIRST AND SECOND PUNCHES

Average of	Compartment I Shelf			Compartment II Shelf			Compartment III Shelf		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
				First Punch					
	+.5	+.3	−.1	−.3	−.3	0	+.3	+.3	+.3
	+.3	+.3	−.2	−.3	−.1	0	+.3	+.4	+.3
	−.2	+.3	+.1	−.3	−.2	−.1	+.1	+.3	−.2
	+.2	0	+.3	−.2	−.3	0	+.4	+.5	+.4
	+.3	+.1	0	−.1	−.2	+.2	+.3	+.3	+.2
Shelf	+.22	+.20	+.02	−.24	−.22	+.02	+.28	+.36	+.20
Compartment		+.15			−.15			+.28	
Cabinet					+.09				
				Second Punch					
	−.1	0	+.1	−.1	+.2	0	+.1	0	0
	+.2	+.1	0	−.2	+.1	−.1	+.3	0	0
	0	0	+.2	−.1	−.2	−.1	+.5	+.1	0
	+.2	−.2	+.2	0	0	+.2	+.4	+.3	−.1
	+.1	0	−.1	+.3	−.2	0	+.3	+.2	−.3
Shelf	+.8	−.02	+.08	−.02	−.02	0	+.32	+.12	−.08
Compartment		+.05			−.01			+.12	
Cabinet					+.05				

[1]Temperature readings minus 30° C.

these temperature readings can be made, they may be considered a fair measure of temperature variation. The maximum variation of temperature for the 45 positions was, at the end of the first punch, 0.8° C., and at the end of the second punch, 0.8° C. The maximum variation of the average temperature on the shelves was, at the first punch, 0.52° C., and at the second punch, 0.4° C. As the compartments are individual units, their average temperature is a measure of the accuracy of adjustment of the individual thermoregulators. The maximum variation of compartments at the first punch in this instance was 0.44° C. and at the second punch 0.13° C. From a consideration of these and similar data, it has been con-

cluded that the maximum ranges of temperature variation of doughs in the whole cabinet is close to ±0.5° C.

Although no direct comparison of the new and old style cabinets has been made, a general idea regarding the variability of replicates can be obtained by examination of typical bakings made by use of each. Table II shows the frequency of various magnitudes of differences between replicates in 4 bakings by the basic formula. In all cases the replicates were baked in the same day, but they were spaced the length of the series; that is, in a series of 25 flours, 1 and 26, 2 and 27, etc., would be replicates. These bakings were made with different flours, but the data have been chosen quite randomly and there is no reason to believe that the skill of the bakers increased after the new cabinet was introduced.

TABLE II

VARIATION OF DUPLICATE LOAVES WITH THE NEW AND OLD CABINETS

Difference Between Duplicates cc.	Frequency			
	New Cabinet		Old Cabinet	
	Bake 1	Bake 2	Bake 3	Bake 4
0	7	0	3	2
5	6	3	5	3
10	4	4	4	3
15	1	9	4	2
20	4	4	1	6
25	2	2	2	4
30	1	1	1	—
35	—	—	1	—
40	—	—	1	3
45	—	1	1	—
55	—	—	—	1
Totals	25	24	23	24
Percentage of Totals exceeding 20 cc. Difference	12	17	26	33

At one time our upper limit of differences accepted in duplicates was 20 cc. and those that showed greater variation than this were repeated. With the old style cabinet the numbers of pairs differing by more than 20 cc. varied from about 25 – 40% while with the cabinet here described they are about 4 – 16%. In other words we now rarely have more than 4 out of 25 pairs that show differences of loaf volume in excess of 20 cc. whereas we formerly had as high as 10 pairs exceeding this limit.

The cabinet described can be easily and inexpensively constructed in any well-equipped shop. The heating elements may be made in the laboratory or purchased at small cost from a supply house. The capacity is 45 small crocks, and if a 5 min. schedule is followed the capacity is without limit for total fermentation times up to 3 hrs. 40 min. It permits speed in handling large bakes and maintains a temperature that varies over the whole range of position by not more than ±0.5° C.

Mehlchemischer Lehrkursus (mit einer Einführung in die Chemie)—by Dr. Karl Schmorl. Second Edition. Verlag Moritz Schäfer, Leipzig, 1930. 102 pages. Paper bound. Price, R. M. 4.

The author states in the introduction that his book is written for the use of scientific research laboratories as well as milling laboratories.

The contents of the book are divided into six main divisions, namely:

I. Cereal grains.
II. Chemical work in the mill laboratory.
III. Supplementary determinations.
IV. Commercial varieties of grain.
V. Introduction to chemistry.
VI. Literature (Books and current periodicals).

Within the compass of 102 pages the author has condensed an enormous amount of information. In the first section 5 pages are devoted to a brief discussion of wheat, rye, corn, rice, barley, oats and millet. Tables of composition and physical constants are given, including the composition of some types of bread.

The second section deals with the physical and chemical work of the cereal laboratory, and occupies half the book. Its subject matter appears quite complete. Literature citations are given at the end of each determination described, and that many references are dated 1930 attests to the fact that the author has endeavored to bring his text up to date. Tables illustrating the results of analyses are numerous, as well as graphic charts and illustrations of equipment.

In Section III, fat, starch, crude fiber, and pentosans are discussed, and methods for their determination given. The entire subject matter is handled in 6 pages.

Section IV lists the types of grain obtained from different sections of the world, and describes their general characteristics.

Section V discusses elementary chemistry, and is an effort to acquaint the non-chemist with the principles of chemistry. It occupies fully one-third of the book. The reviewer has difficulty in seeing how this brief description will enable one unfamiliar with chemistry and chemical manipulations to conduct such determinations described in Section II, as, for instance, diastatic activity, electrolytic conductivity of flour extracts, or the Kjeldahl nitrogen determination. For the non-chemist who wishes merely to review the subject to obtain general information, this compact treatise is excellent. The chemist will find the description of the analytical determinations entirely adequate. The American chemist will find much of interest to him.

The reviewer was interested in the description of novel, rapid methods of analyses, presumably practiced by German cereal laboratories.

The book is concluded by listing 28 books and scientific journals that deal with the subject matter of cereal chemistry.

CHARLES G. FERRARI.